

# Foliations and Lineations

# Foliation and Lineation

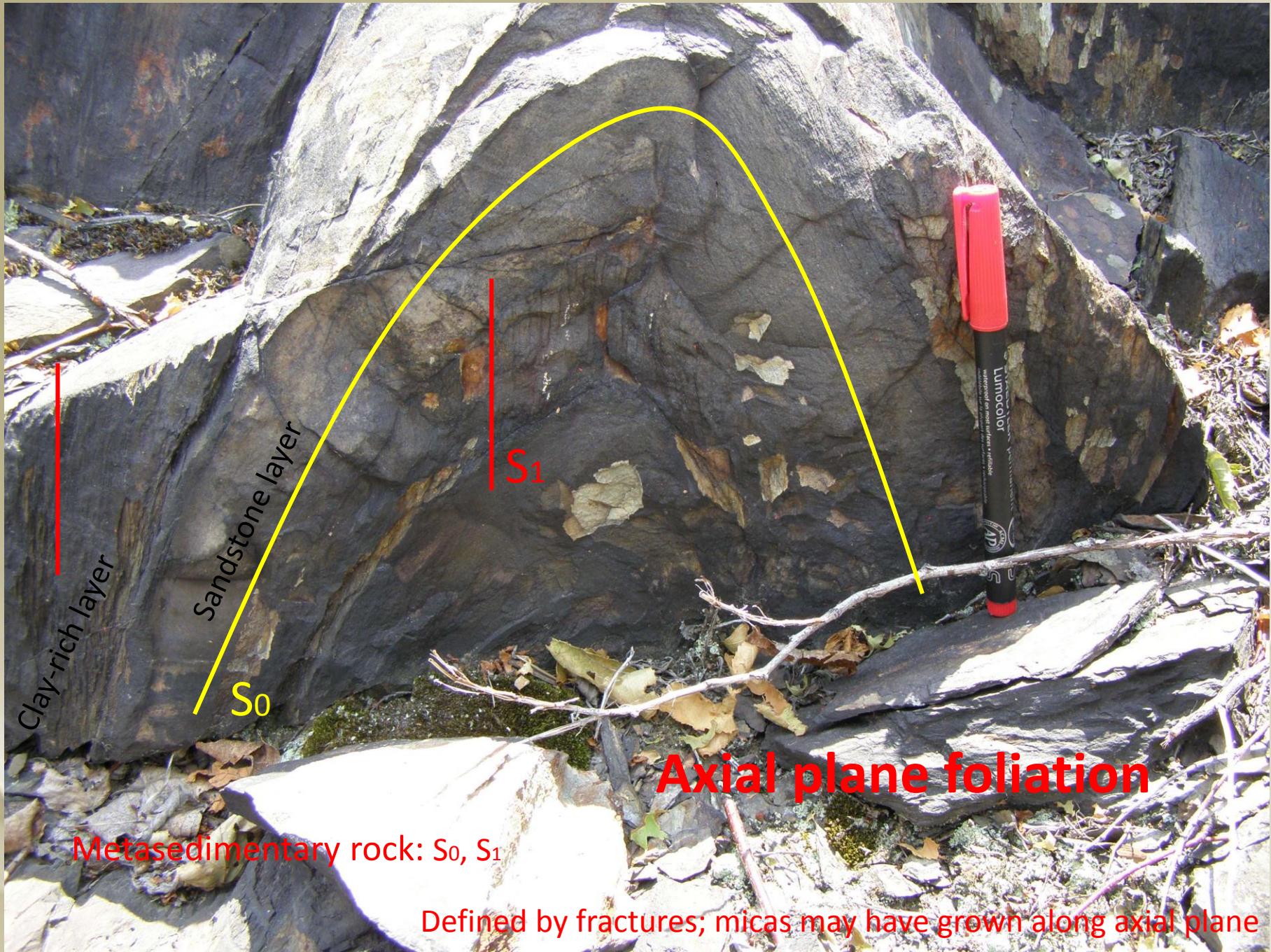
- Penetrative planar/linear feature
- Product of deformation and accompanying metamorphism

In some textbooks, any penetrative planar structure (including some primary structures, such as bedding) is called a foliation.

The term  $S$  (surface) is normally used to indicate the planar features especially when overprinting relationship is shown at one outcrop.  
 $S_0$ : bedding

# Outline

- Recognizing foliations and lineations
  - Foliation ( $S_i, i \geq 1$ ) or bedding ( $S_0$ )
  - What defines foliation/lineation
- Some mechanisms for development of foliations/lineations
- Foliation and folds
  - Foliation bedding relationship
- Recognizing Overprinting





Bedding S0 or tectonic  
foliation S1 ?



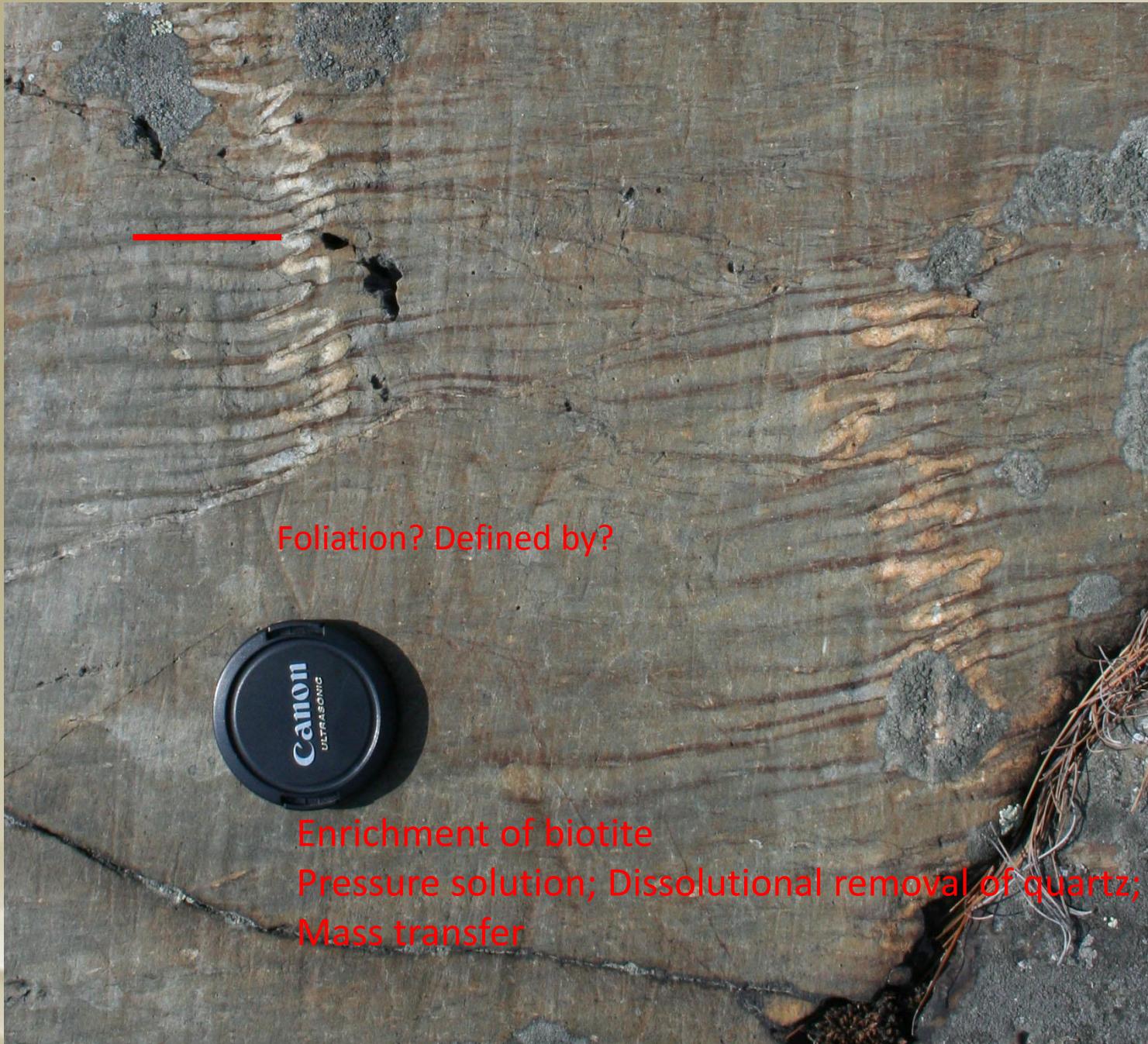
Can be So/S<sub>1</sub>



Early foliation/bedding was almost obliterated.



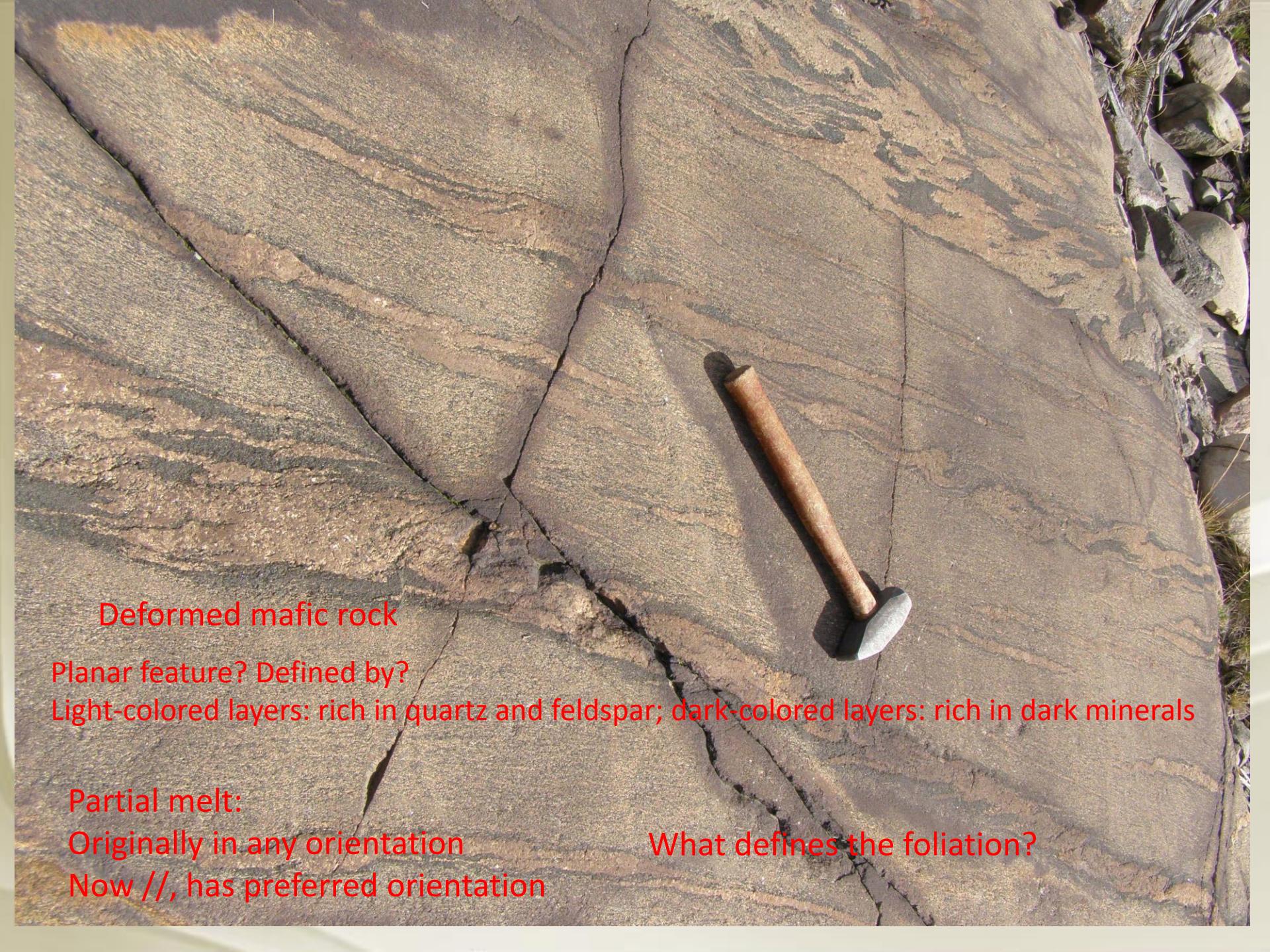
Metasedimentary rock.  
Where is bedding? Where is foliation?



Foliation? Defined by?

Enrichment of biotite

Pressure solution; Dissolutional removal of quartz;  
Mass transfer

A large, dark-colored mafic rock outcrop showing prominent linear foliation. The rock has a layered appearance with alternating light-colored (quartz-feldspar-rich) and dark-colored (dark mineral-rich) layers. A hammer is placed horizontally across the rock to provide a sense of scale.

Deformed mafic rock

Planar feature? Defined by?

Light-colored layers: rich in quartz and feldspar; dark-colored layers: rich in dark minerals

Partial melt:

Originally in any orientation

Now //, has preferred orientation

What defines the foliation?



Foliation: defined by compositional layering

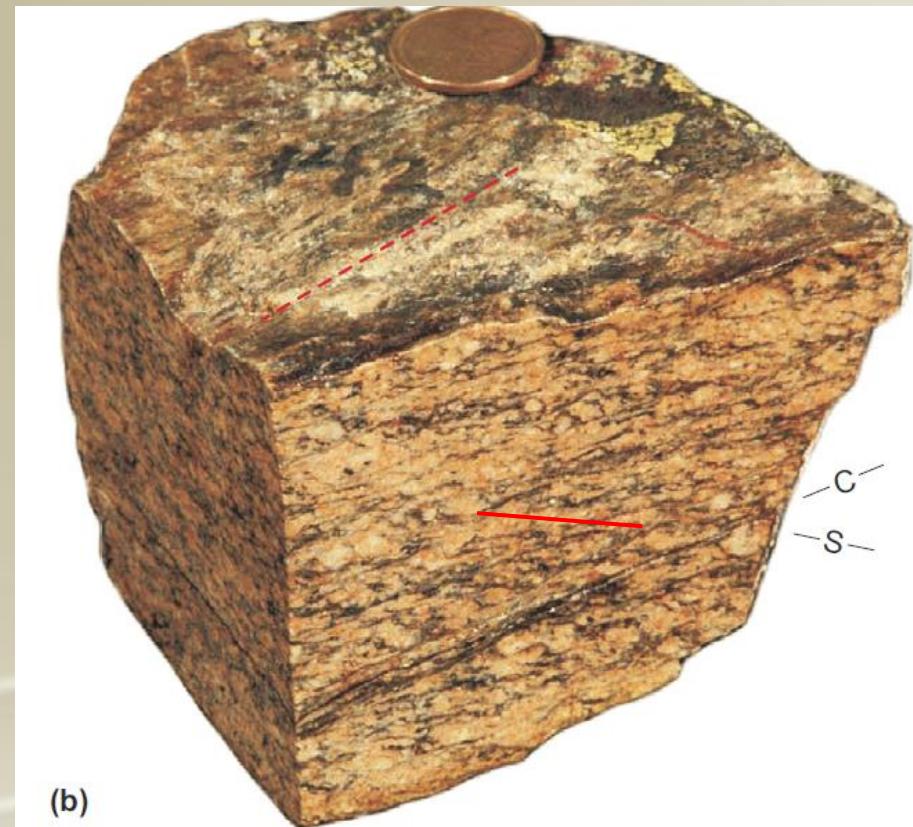
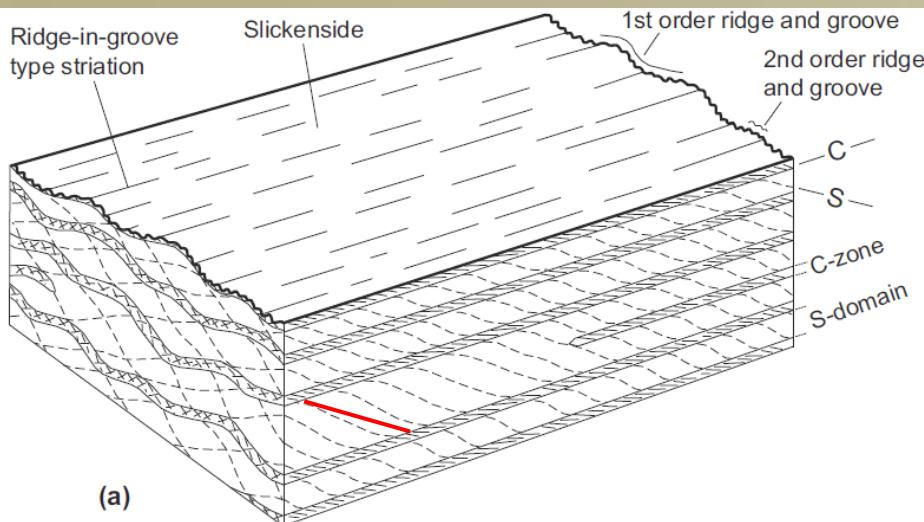


Foliation: defined by compositional layering  
Foliation is axial planar to the fold



Pancake?

Cigarette? Foliation? Lineation?

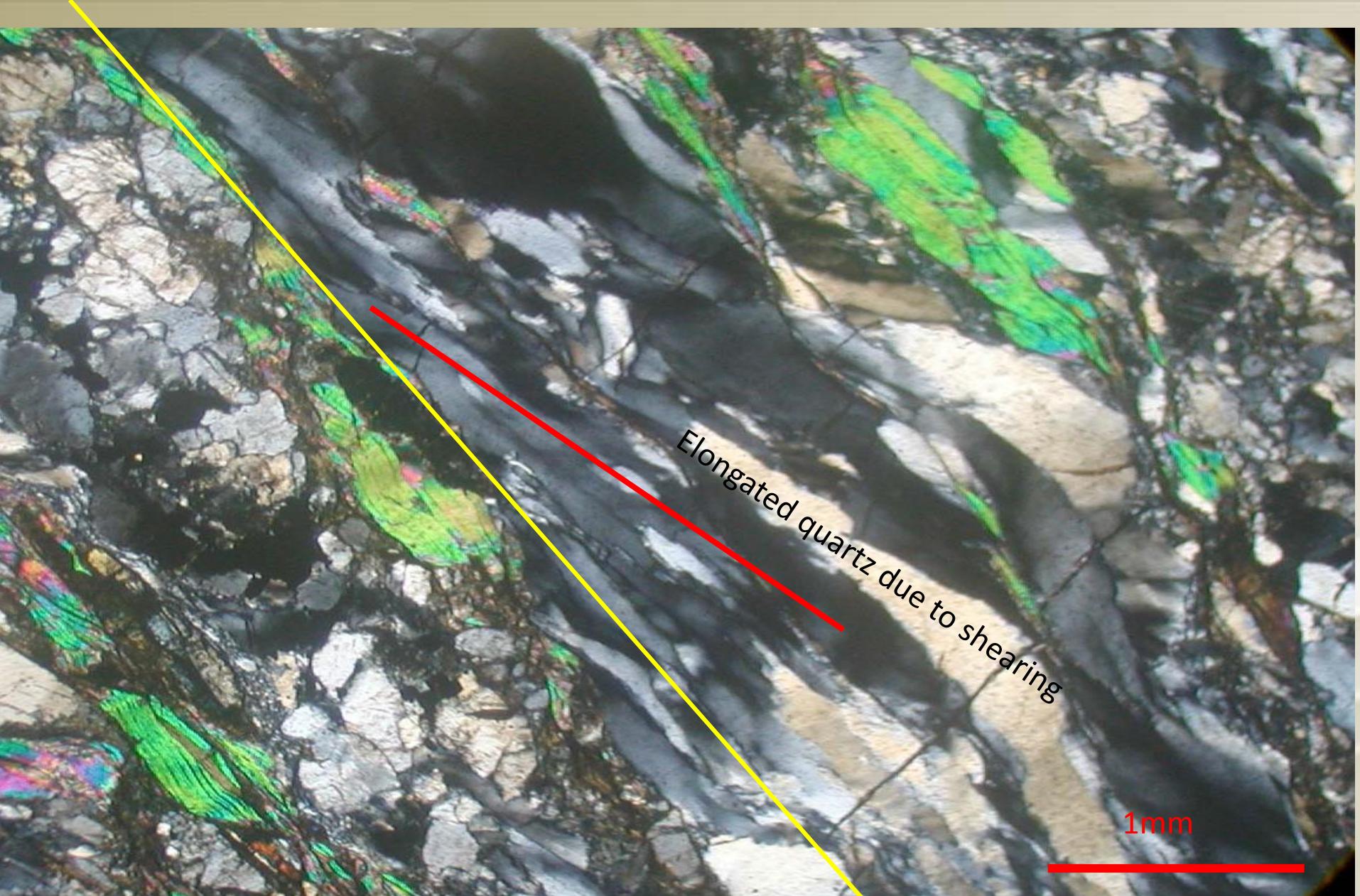


Lin et al. (2007)

S plane: A plane defined by long axis and intermediate axis of minerals

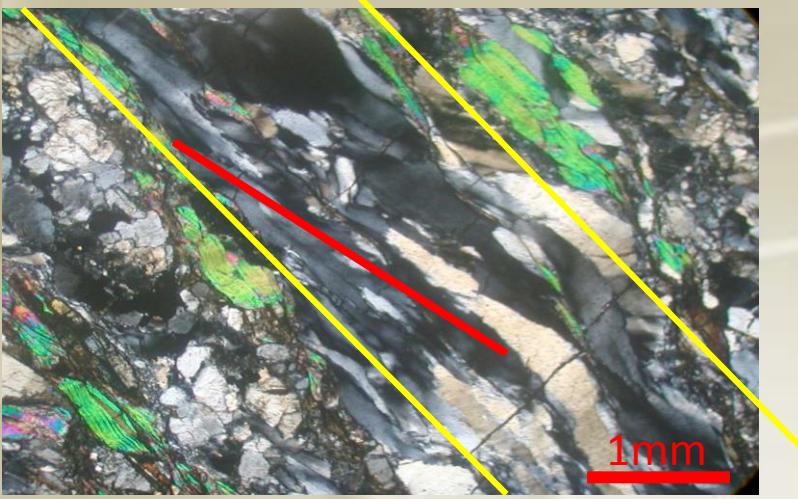
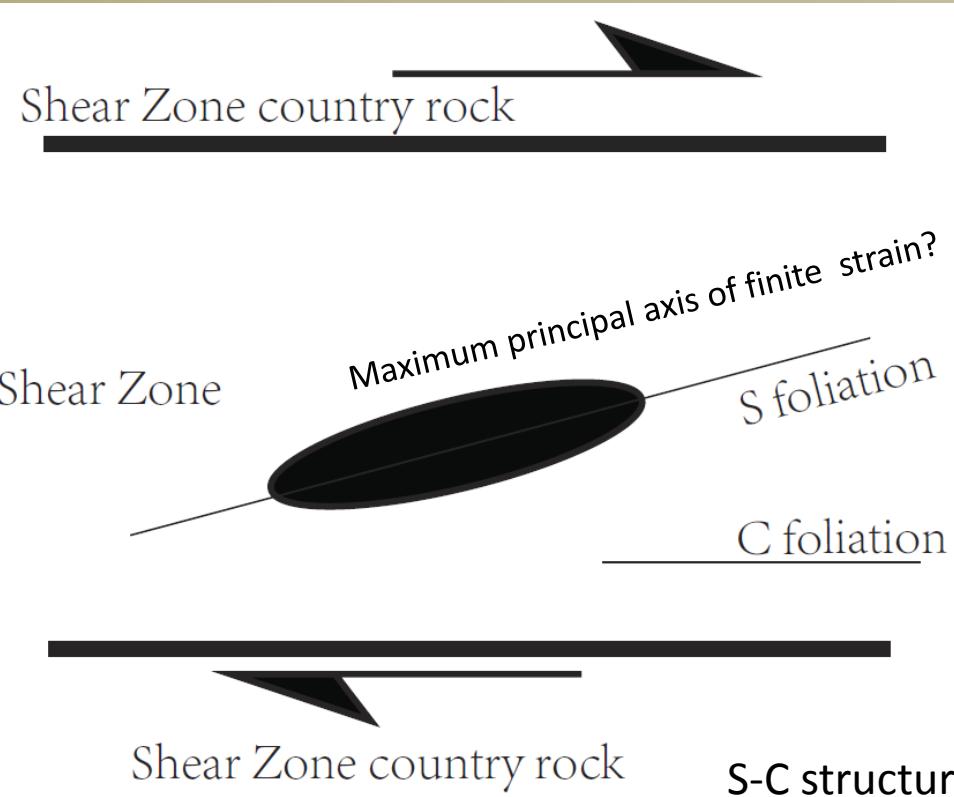
C plane: micro-scale strain localized tabular zone; Mica normally along

Granitic Mylonite



Shape (s) foliation; mineral lineation

C foliation (C comes from the French word “cisaillement”, and it means “shear”)

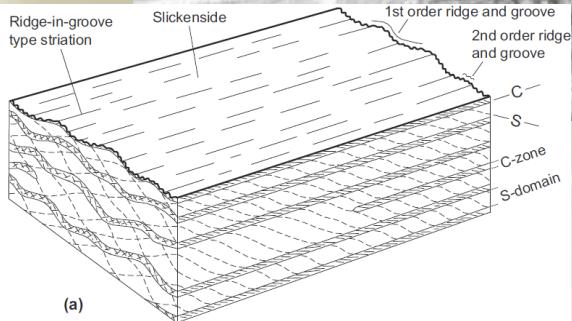
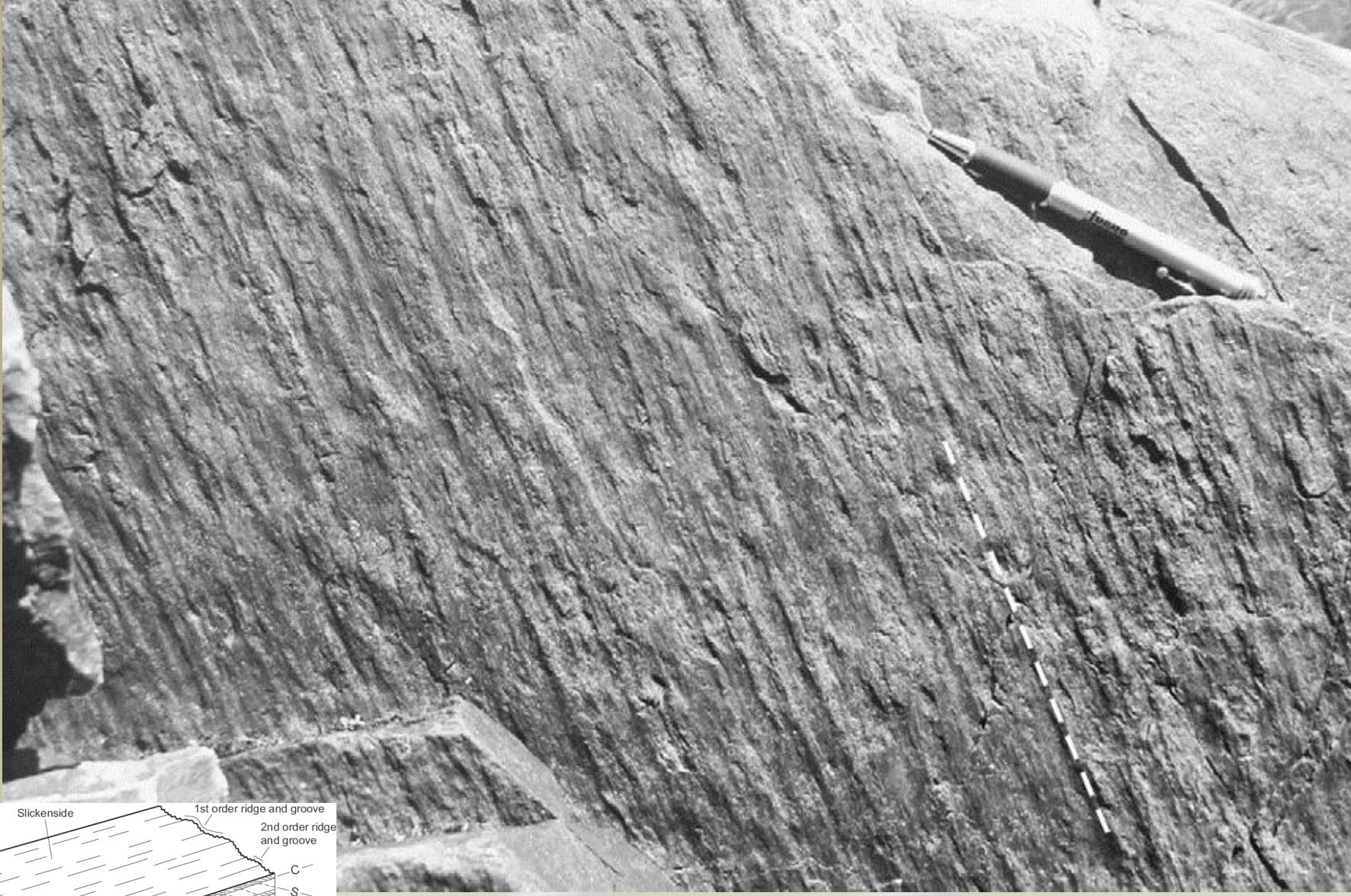


**Before deformation: Equidimensional**  
**After shearing: elongated**

What is the shear sense?

Maximum principal axis of finite strain?

In the above animation, when strain is high enough, the long axis //shear direction. But may not true in other shearing



Lin et al. (2007)

Slickenside striation on C foliation

Striation is along shear direction  
S and C foliations develop  
in shear zones; Mylonite



Undulose extinction

Passchier and Trouw (2006)  
Dynamically recrystallized quartz

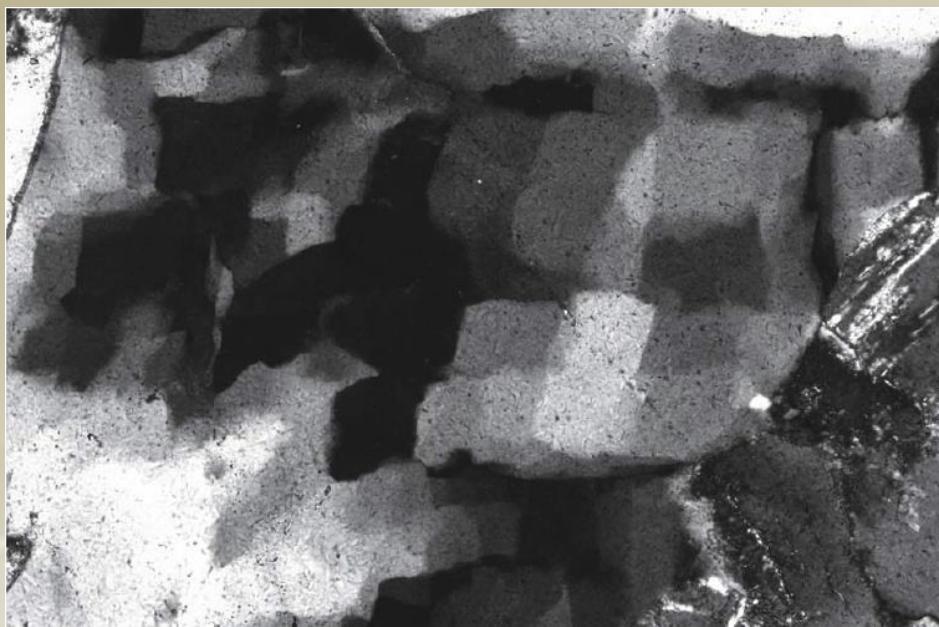
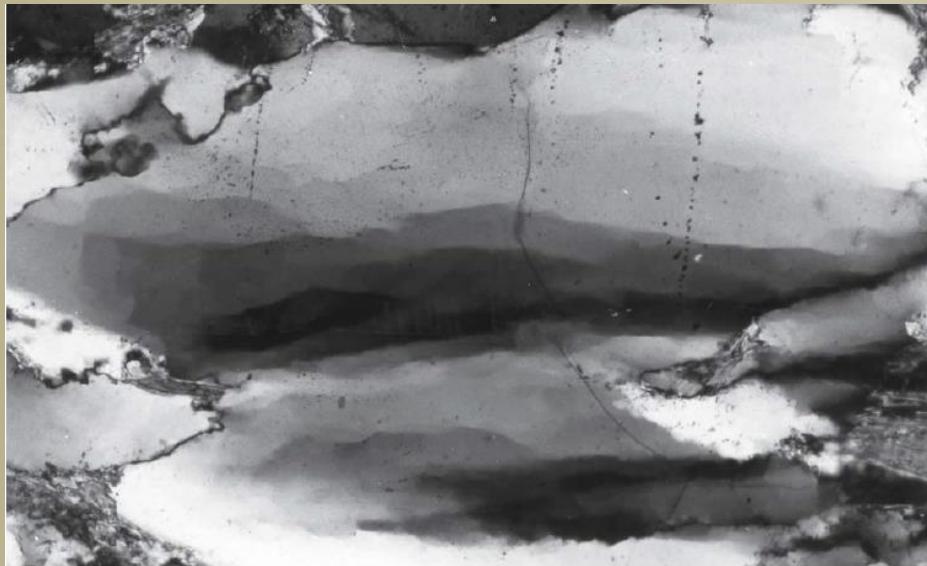
Grain size: bimodal distribution  
Porphyroclasts; matrix



Undulose extinction

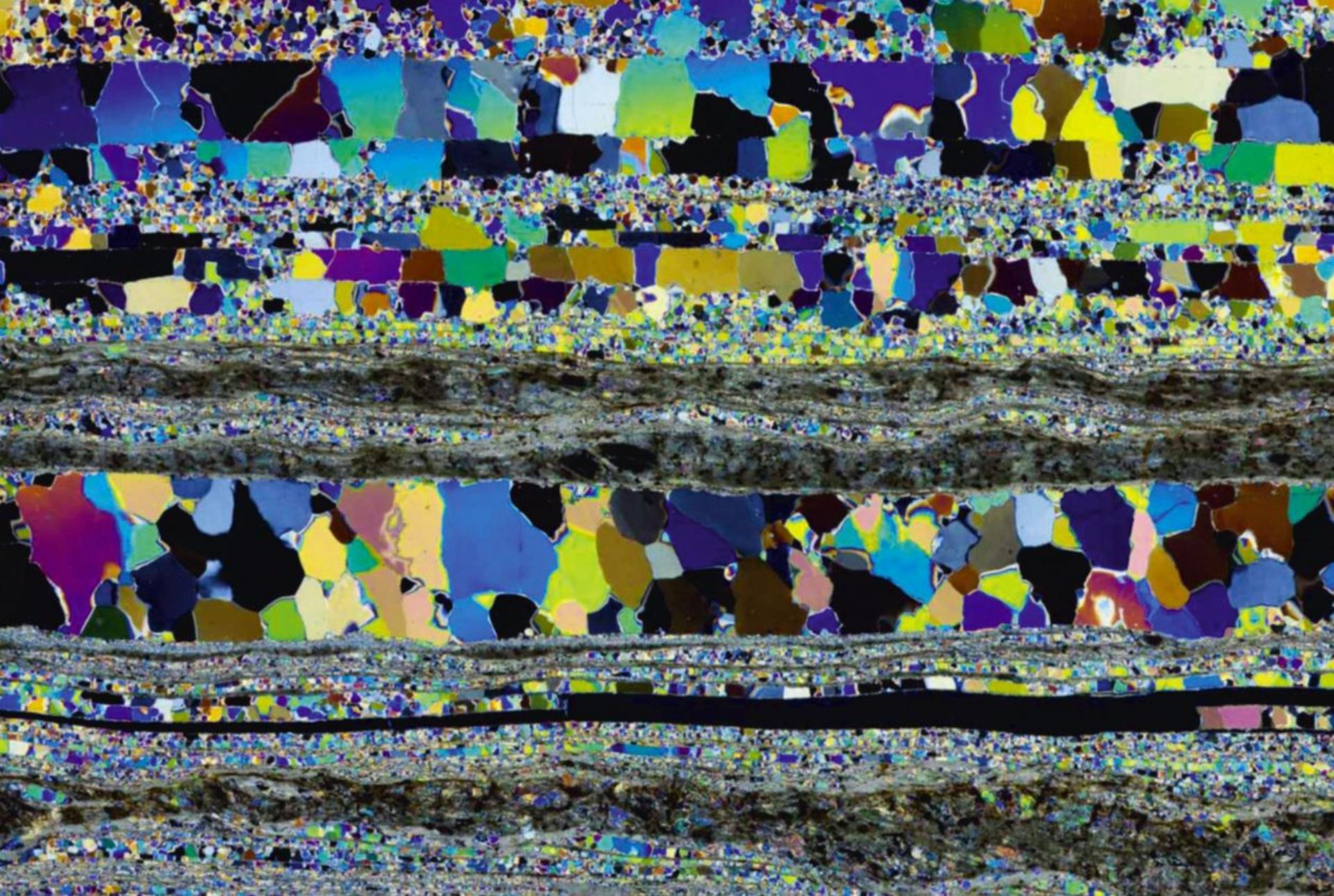
From internet

Crystal lattice is bent;  
Lattice orientation varies  
from one part of the  
crystal to another part of  
the crystal



Passchier and Trouw (2006)

Original one quartz grain: now lattice orientations are different in patches: Subgrains

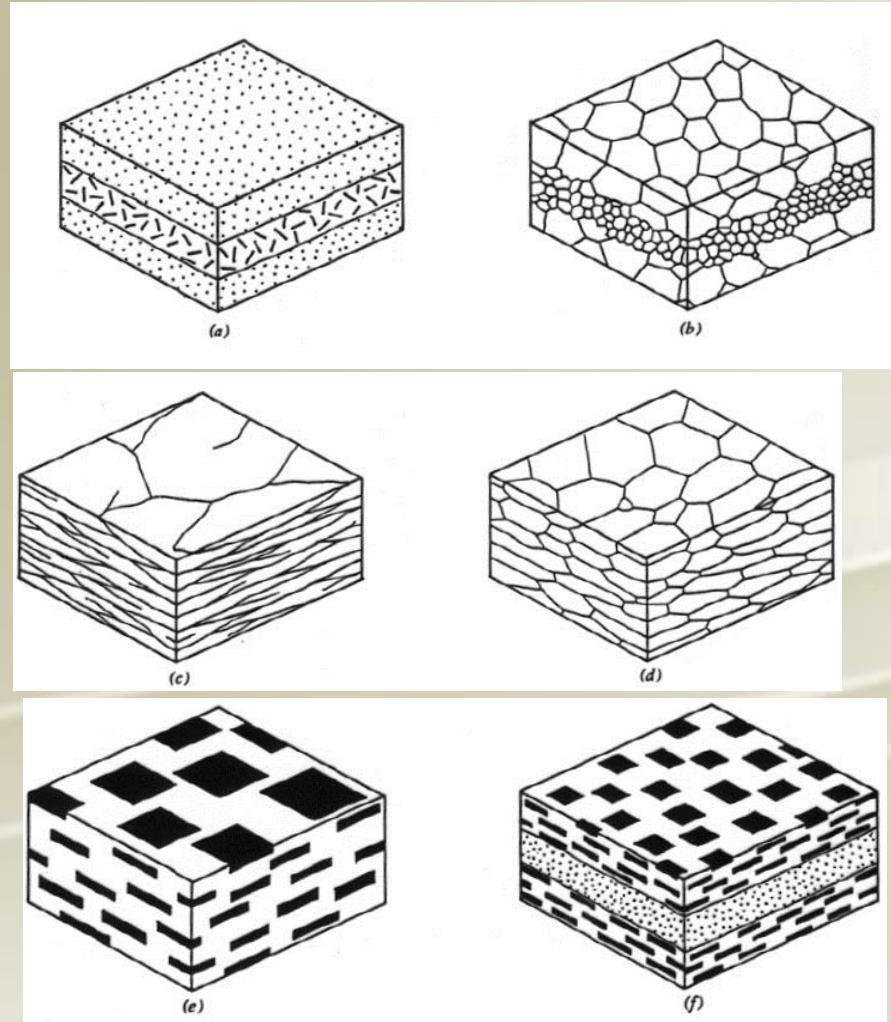


CPL with a Gypsum plate inserted  
Passchier and Trouw (2006)

Foliation defined by composition, grain size/texture

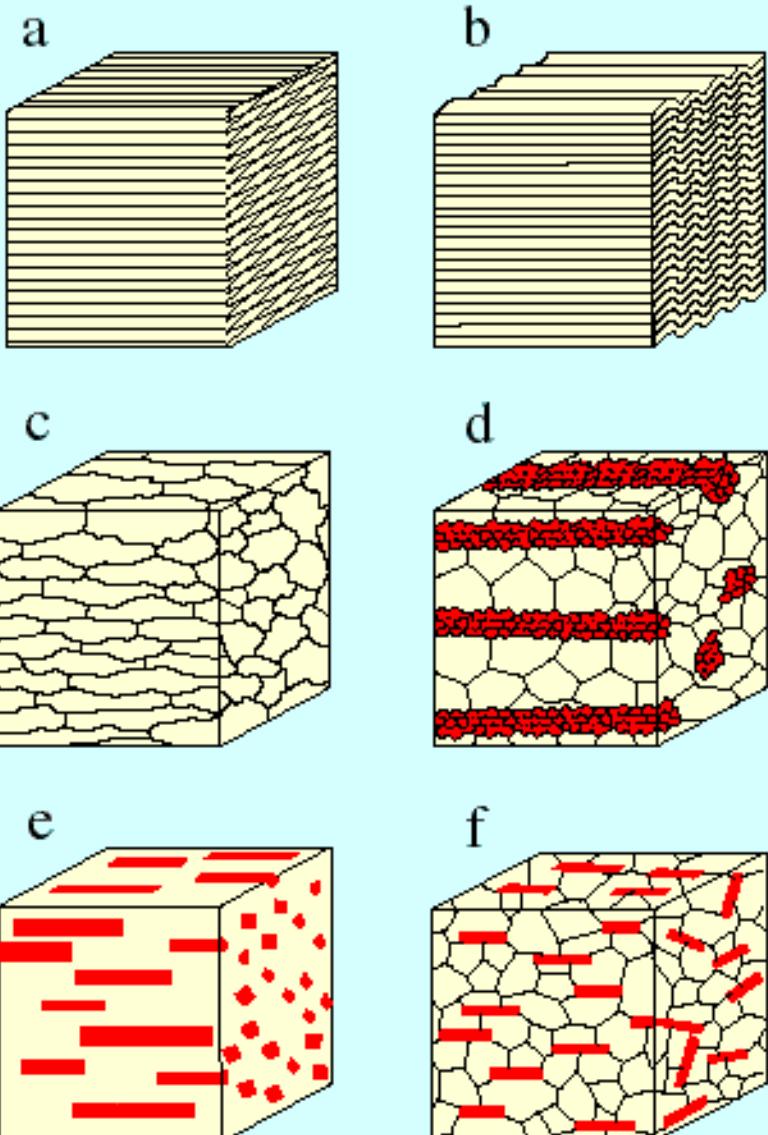
# Foliations

- **Foliation can be defined by:**
- 1. Composition  
(compositional layering)
- 2. Grain size/textured variation
- 3. Closely-spaced fractures
- 4. Shape of mineral grains,  
clasts, pebbles etc.
- 5. Alignment of platy minerals  
(e.g., mica)
- 6. A combination of above



# Lineations

Intersection lineation  
Fold axis  
Elongated minerals/mineral aggregates/clasts



# Foliation or Cleavage

If a foliated rock tends to break apart (*cleave*) along the foliation, the foliation is often called a cleavage.

Some foliations such as compositional banding in metamorphic rocks do not cleave along the foliation easily.

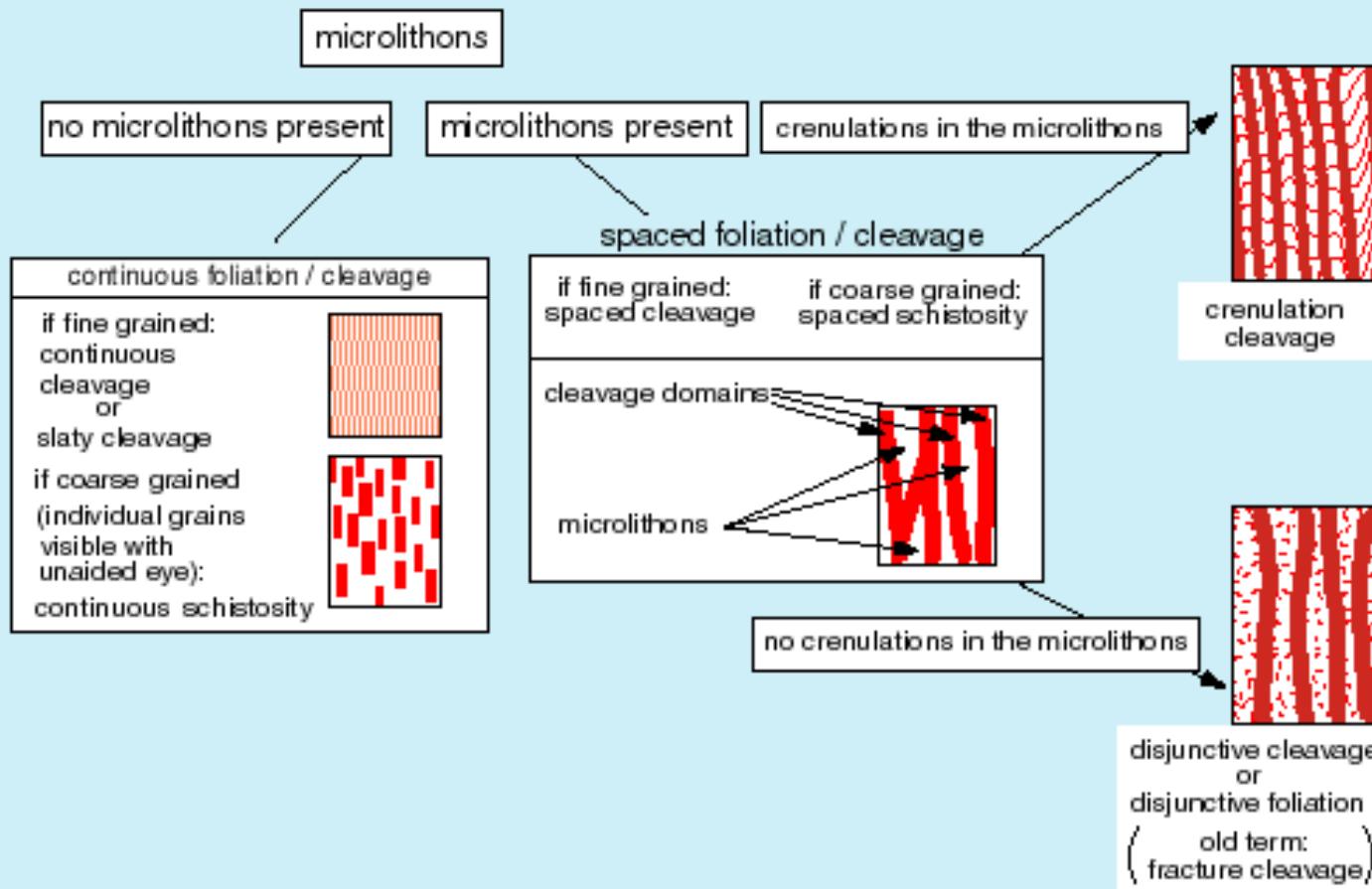
# Foliations associated with folds

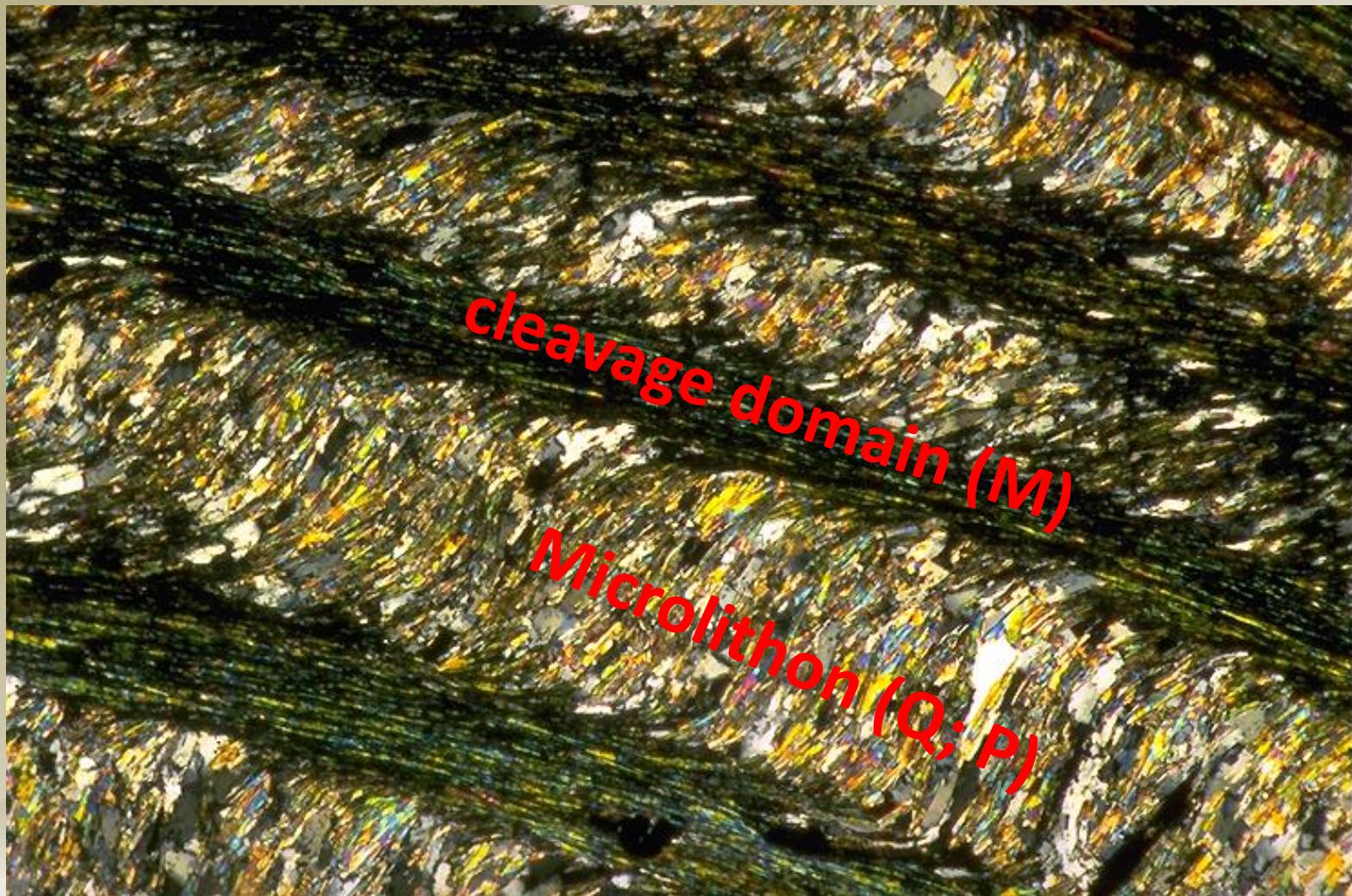
## Axial plane foliations

- slaty cleavage (in slates)
- schistosity
- crenulation cleavage
  - microlithon
  - cleavage domain
- differentiated layering
- transposition foliation

# Morphological classification of foliations

## Morphological classification of foliations (using an optical microscope)





Passchier and Trouw (2006)

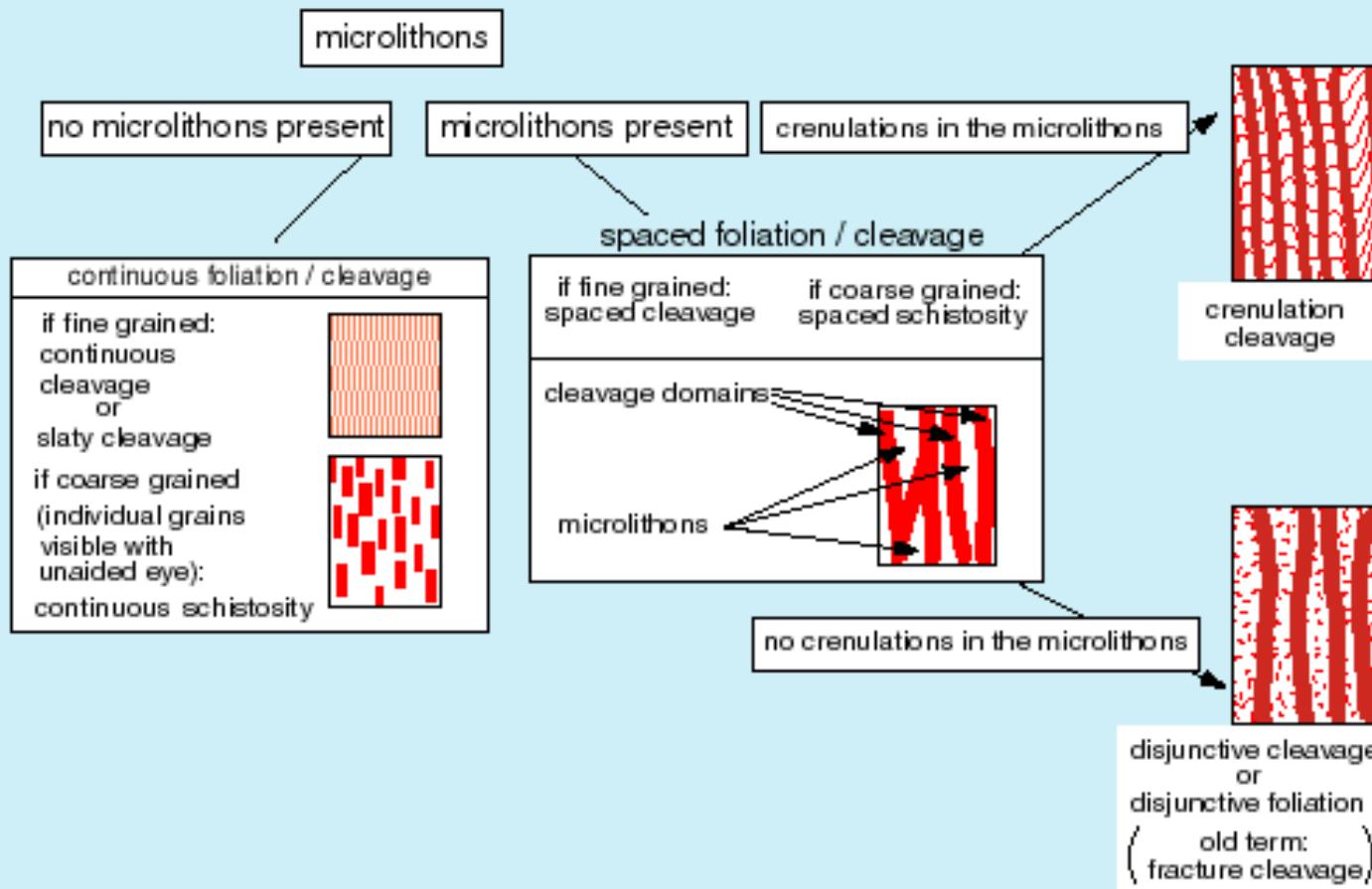
Differentiated layering

Folded (Crenulated)

Differentiated crenulation cleavage

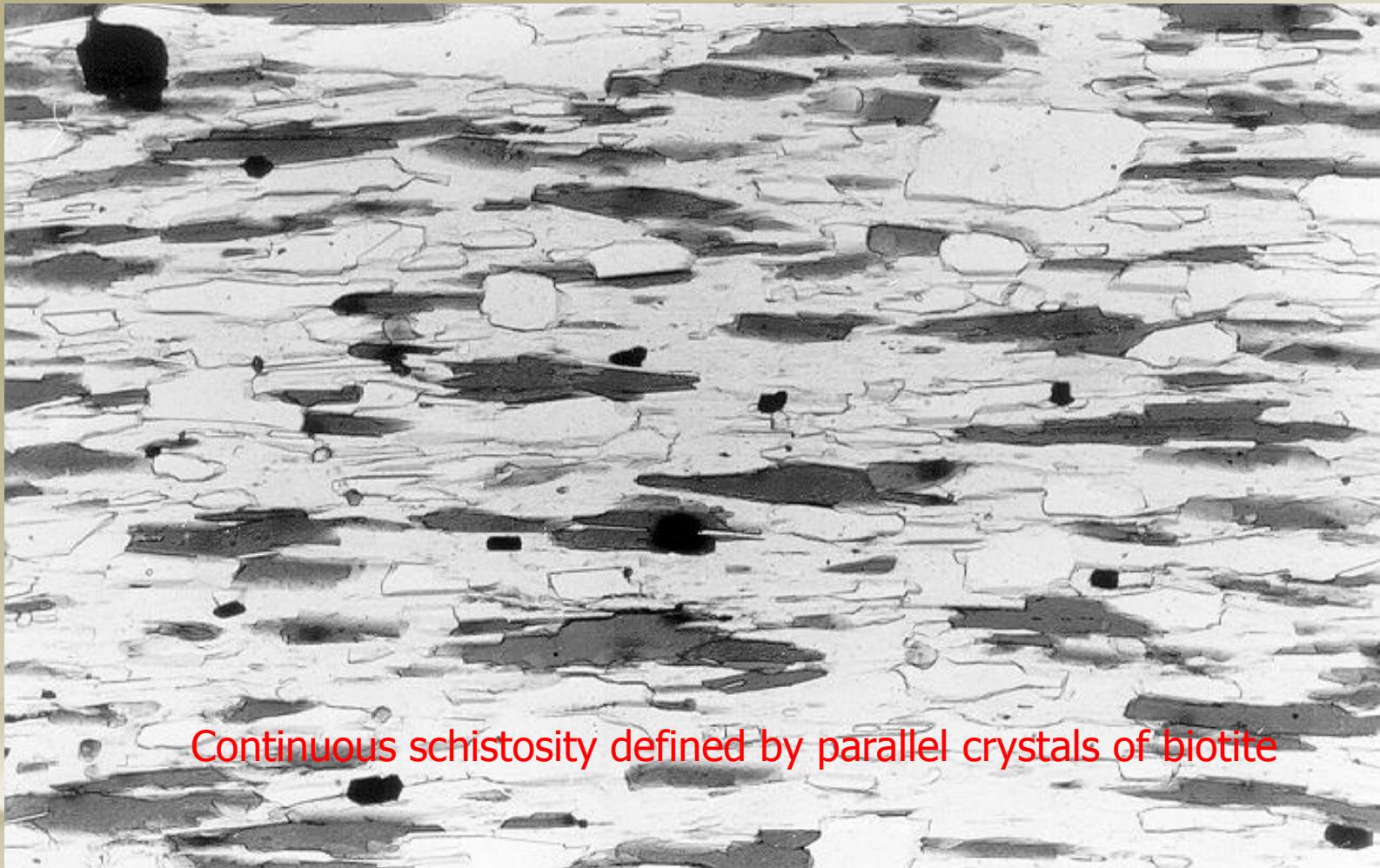
# Morphological classification of foliations

## Morphological classification of foliations (using an optical microscope)



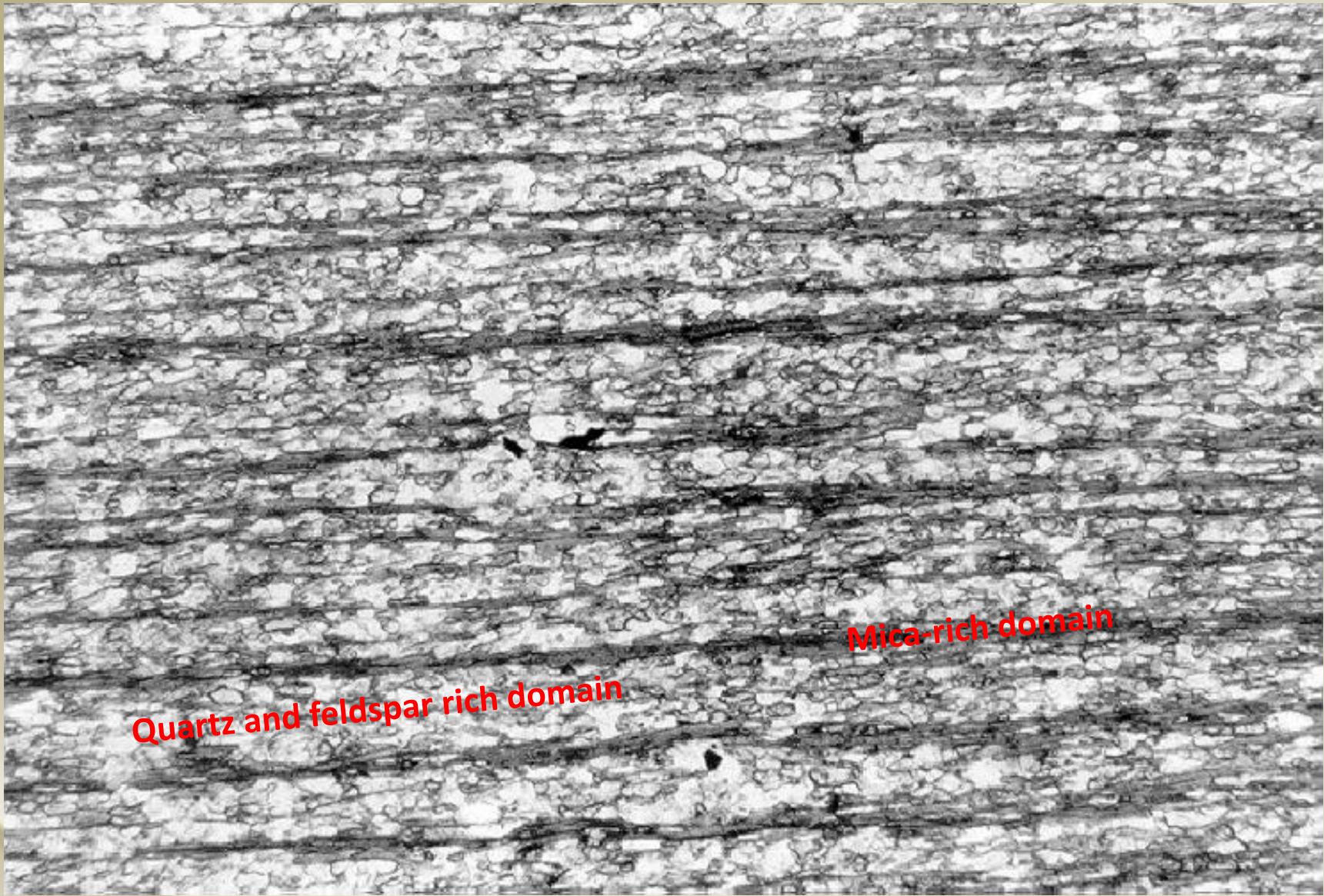
Passchier and Trouw (2006)

# According to the classification, which one is this foliation?



Continuous schistosity defined by parallel crystals of biotite

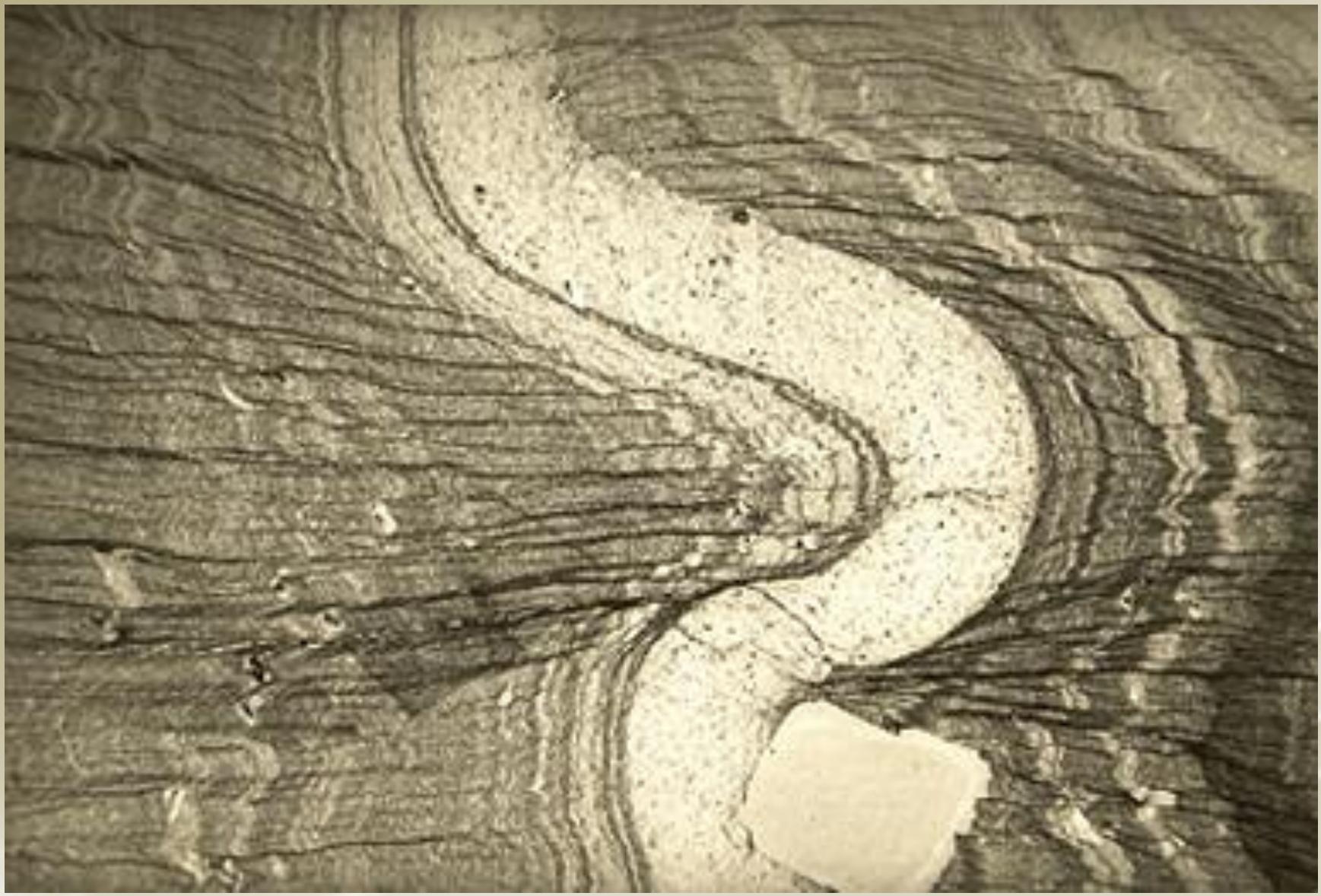
# What foliation is this?



Passchier and Trouw (2006)

Width of view: 1.8mm

Disjunctive cleavage defined by alternative Quartz-rich and mica-rich domains



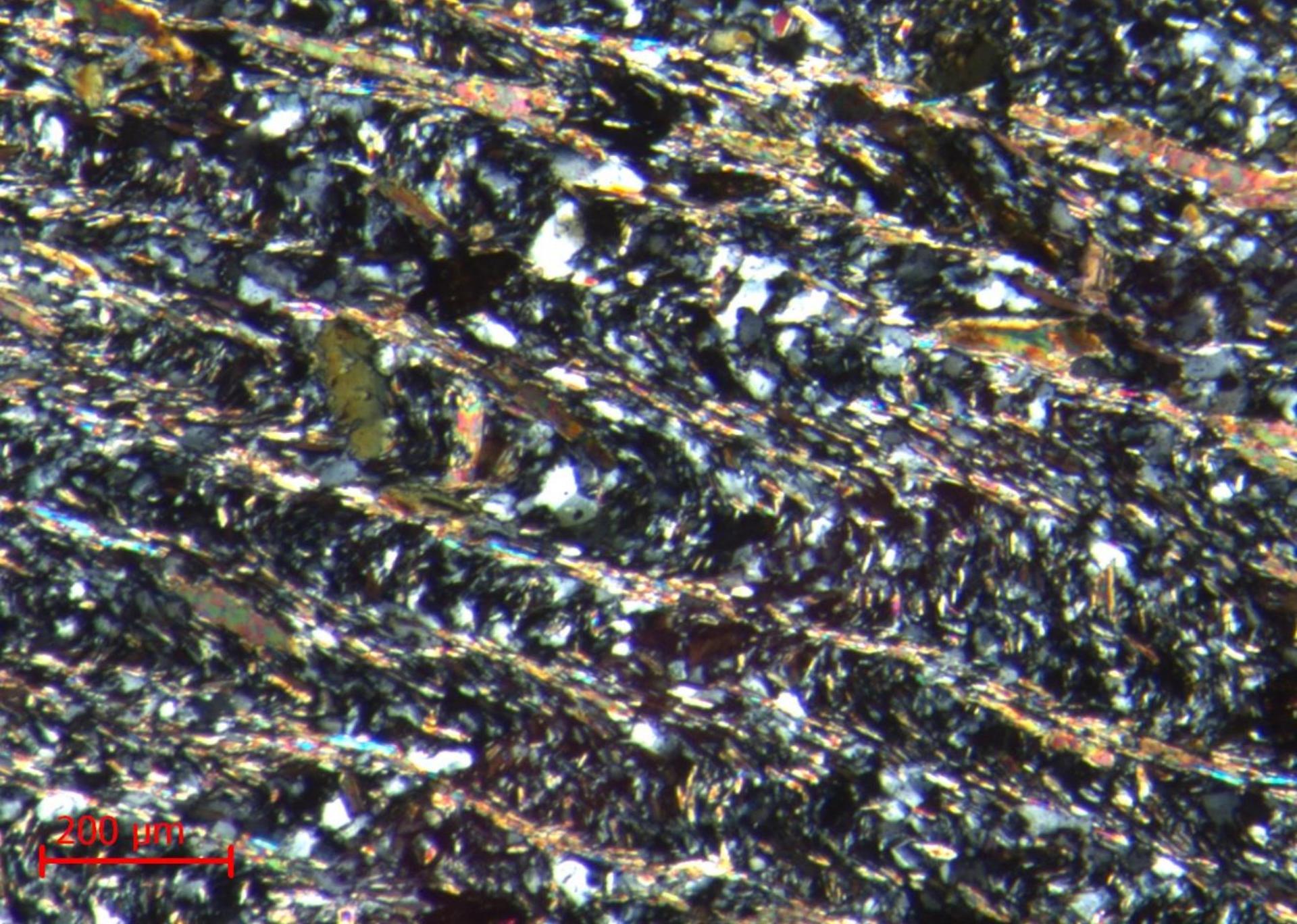
From a textbook

Bright: Rich in quartz; Grey: rich in clay

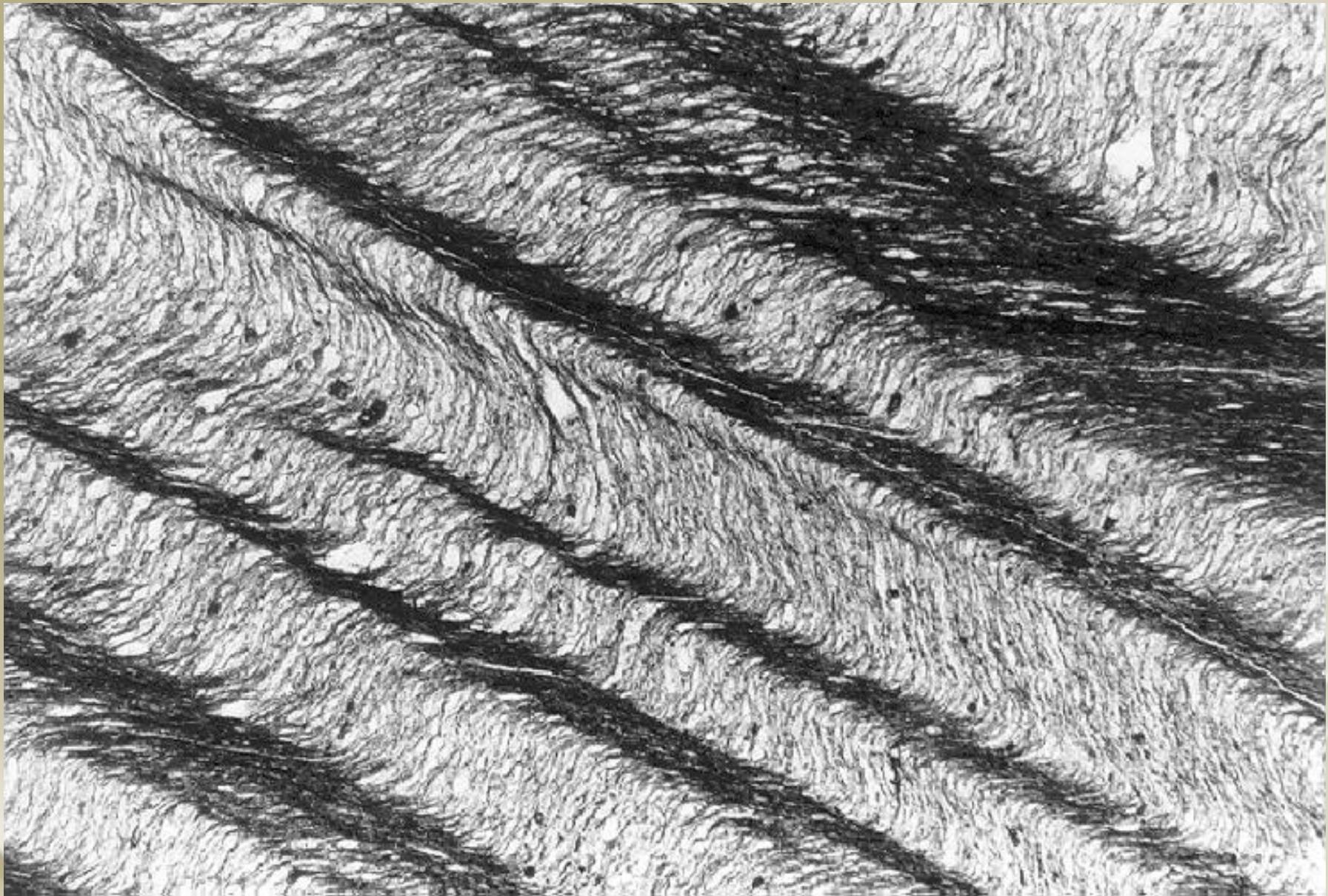
Dark: Oxides and some platy minerals; Insoluble residule; Solution seam

Is folded (crenulated); crenulation cleavage

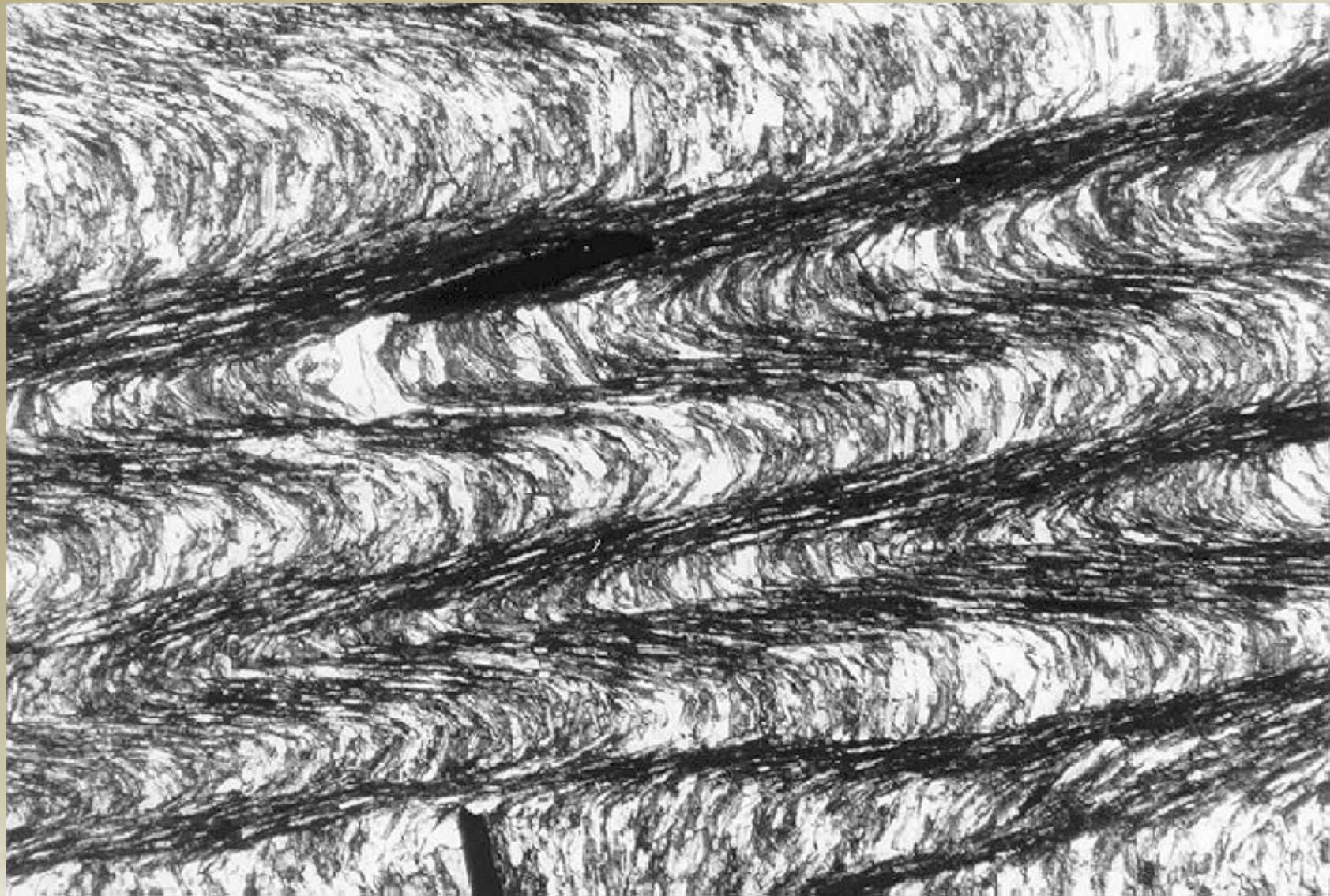




200  $\mu\text{m}$

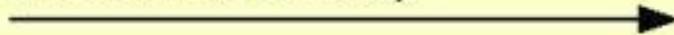


Passchier and Trouw (2006)

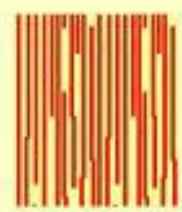
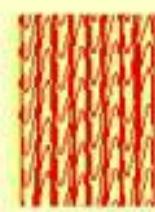
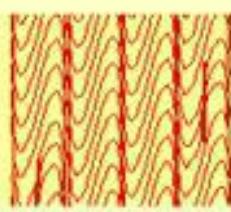
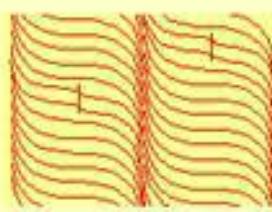
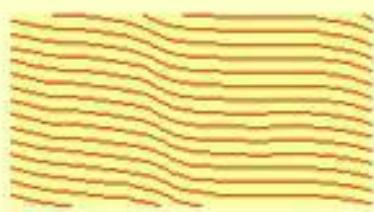


Passchier and Trouw (2006)

Deformation intensity



a



T  
↓

b

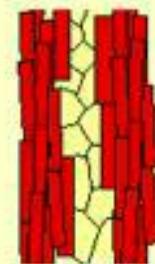
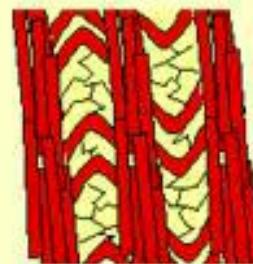
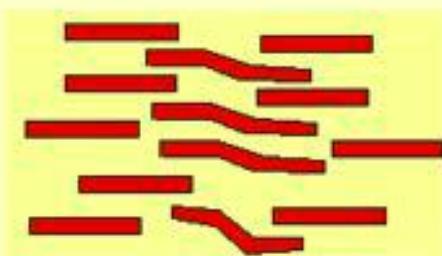
1

2

3

4

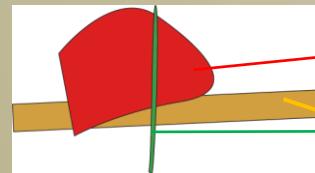
5



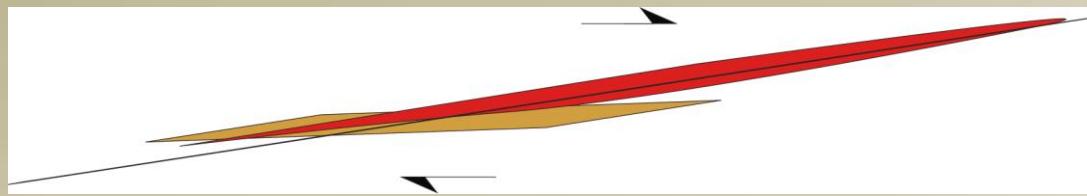
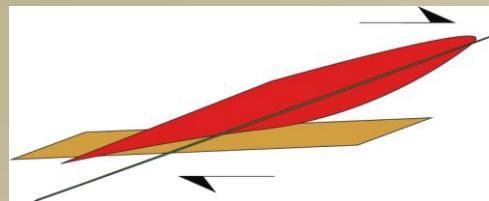




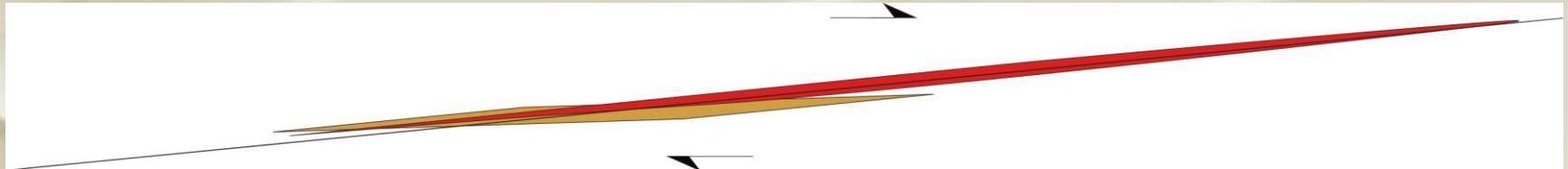




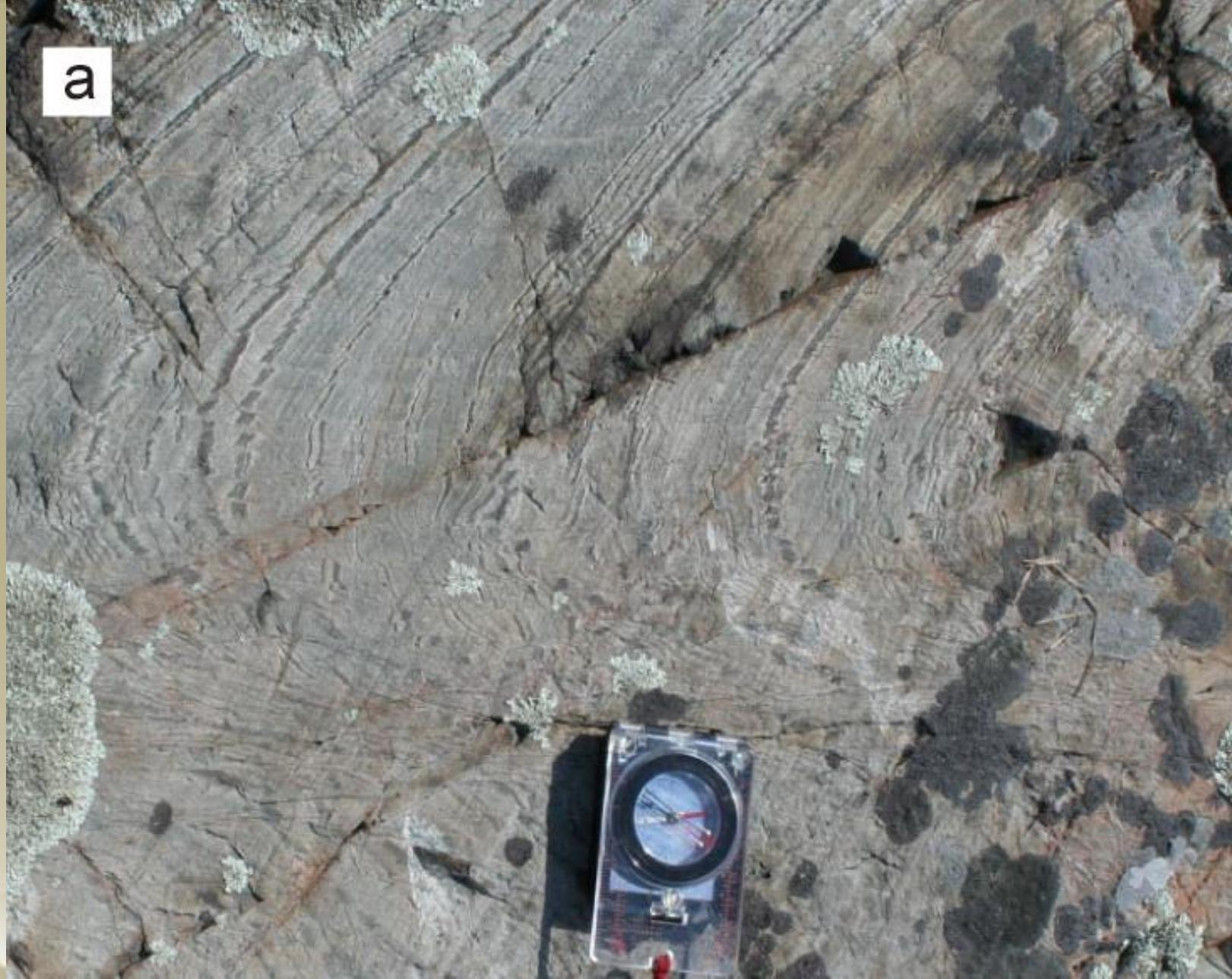
• Pluton  
• Dike  
• bed



Stretched into  
lenticular shape in 3D;  
Long axis rotated to be  
horizontal

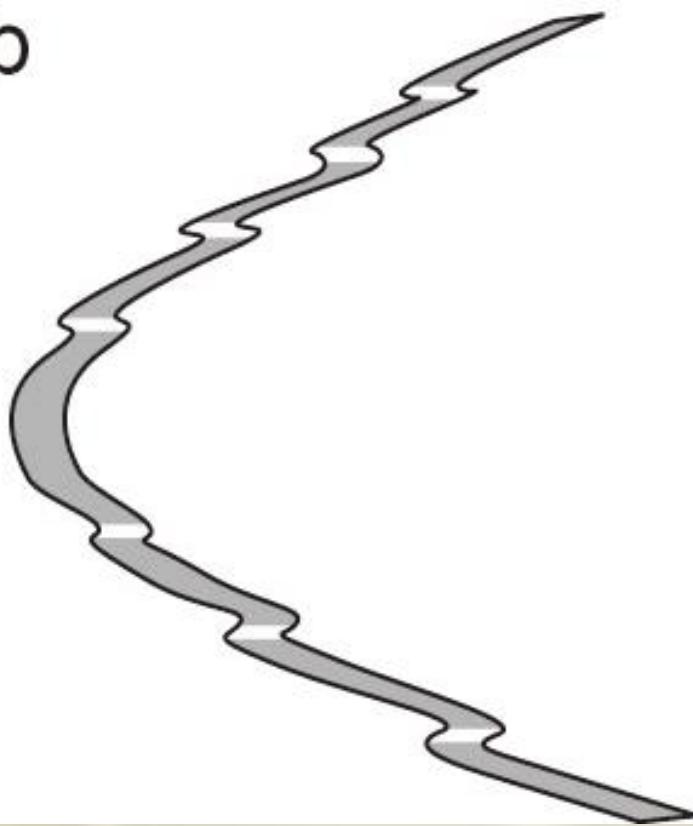


a

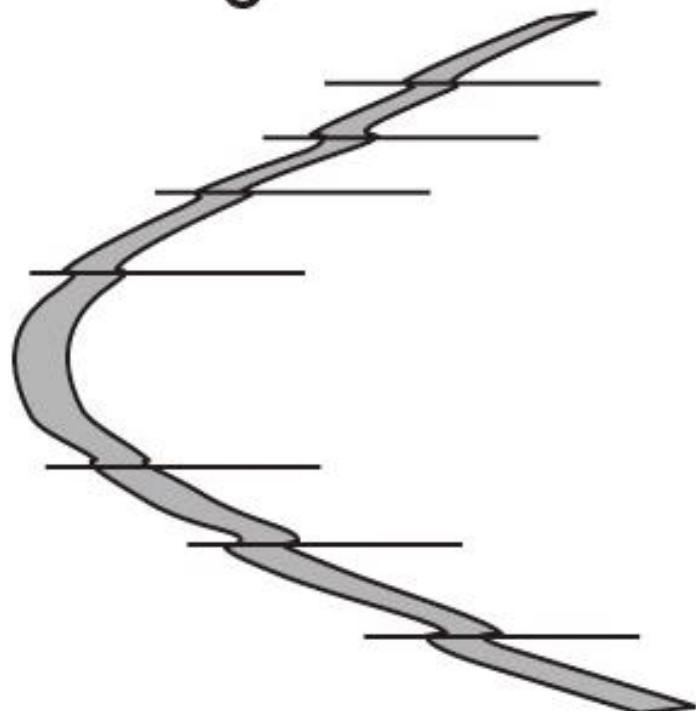


What is the dominant mechanism for the foliation?

b



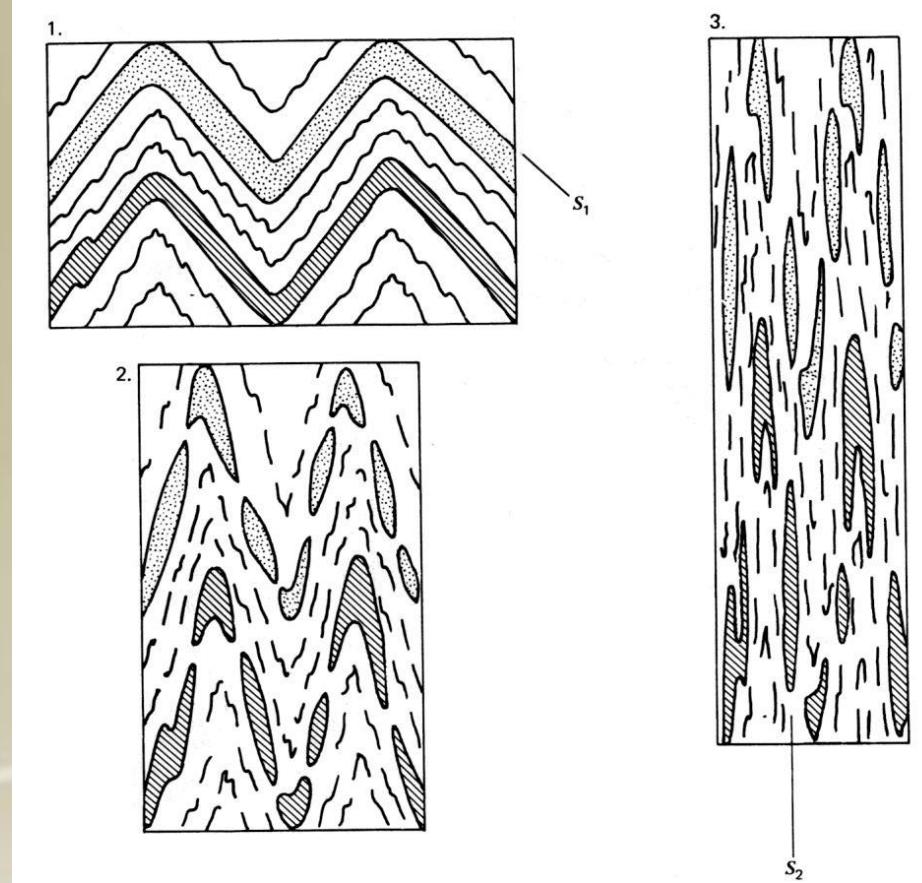
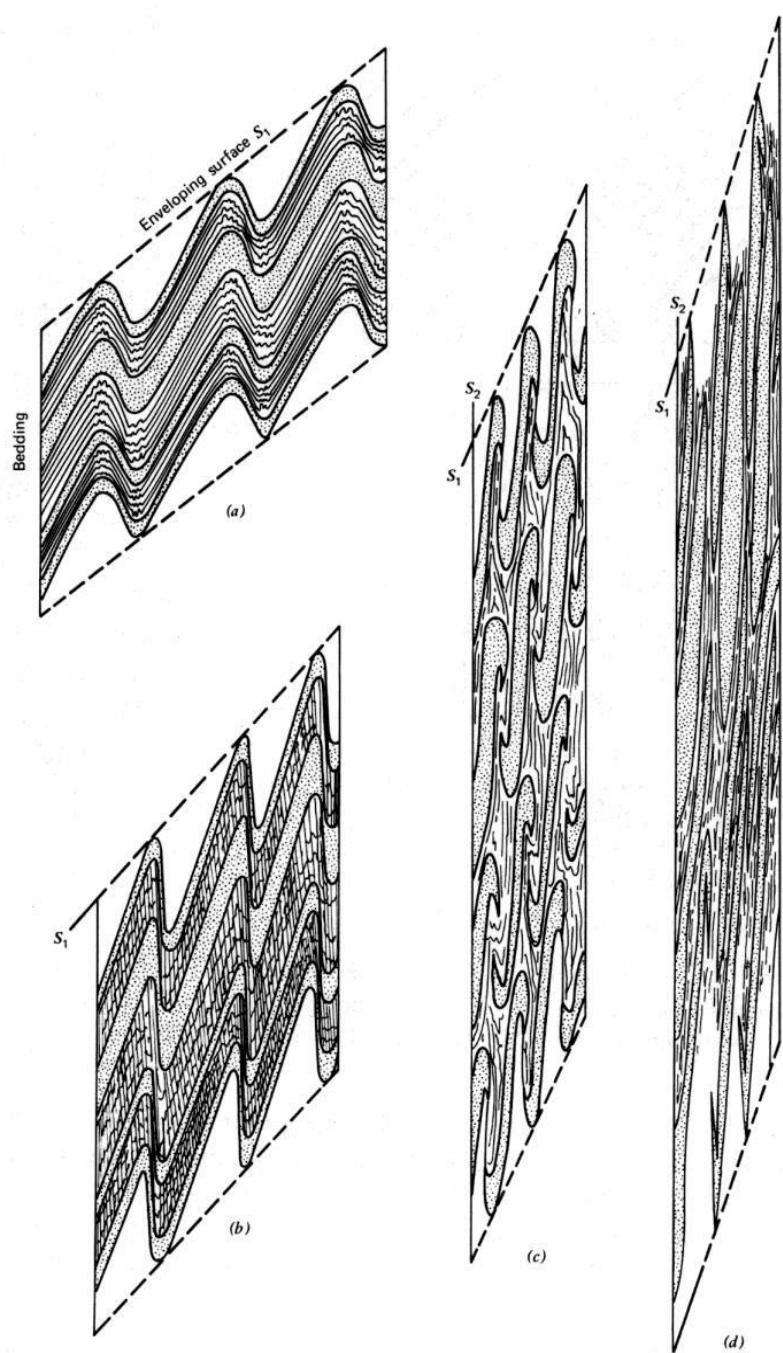
c



Deformed minerals are more soluble than undeformed ones.



Limbs of folds were sheared out





Sharpie

CD/DVD MARKER

FINE/ULTRA FINE

(AP)

# Bedding and foliation relationship



Which is likely to be the bedding geometry?

Answer: The red one

# Bedding and foliation relationship

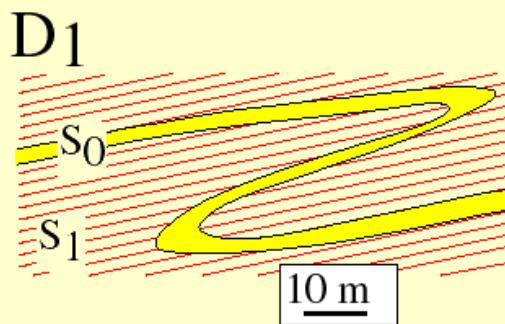




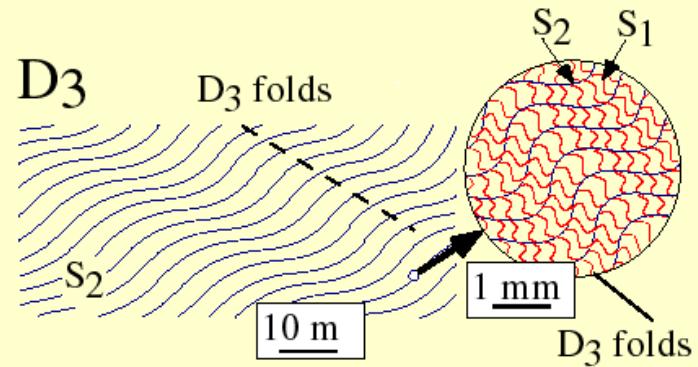
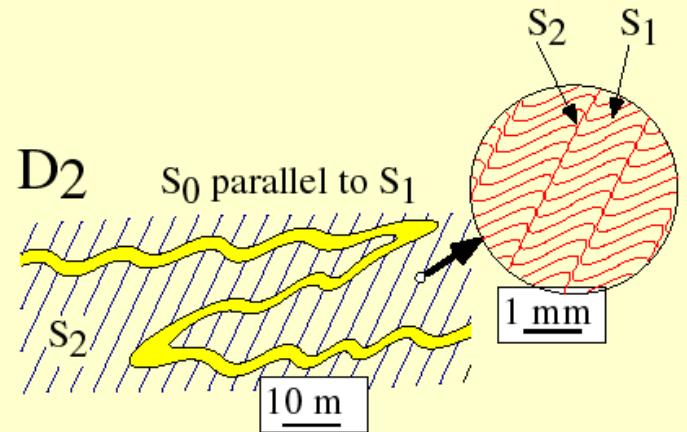
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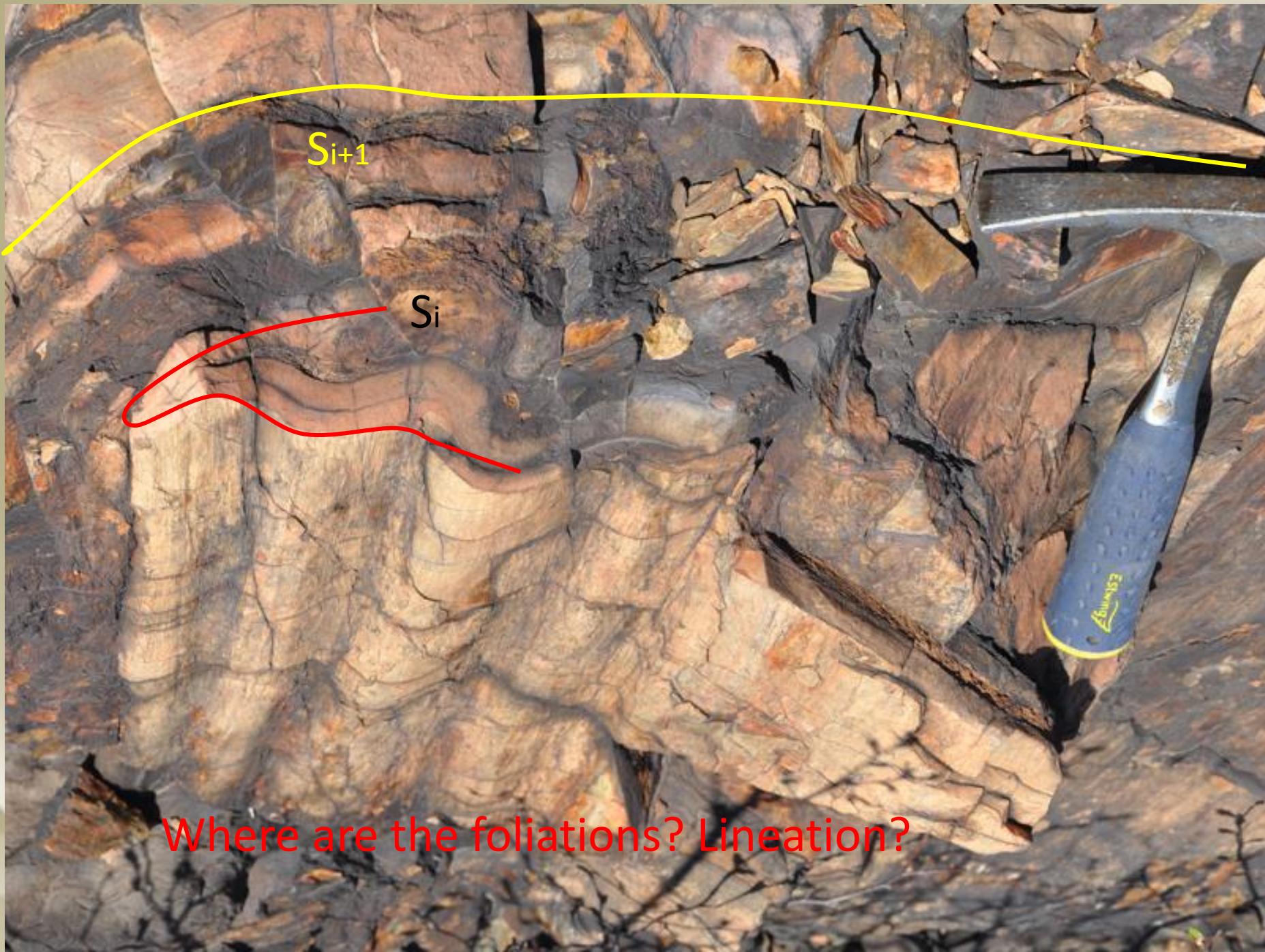
# Schematic presentation of a comma sequence of foliation development



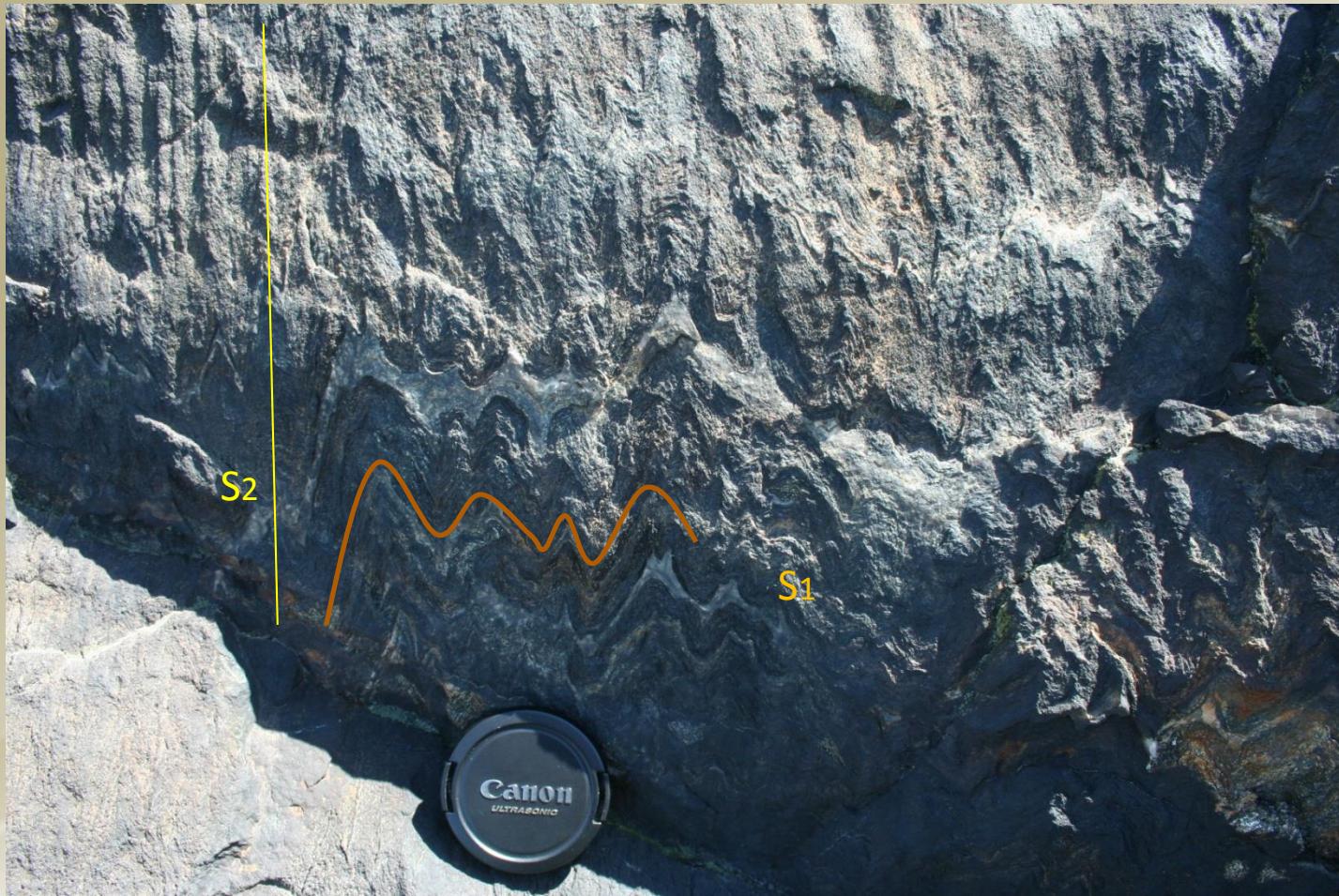
Passchier and Trouw (2006)

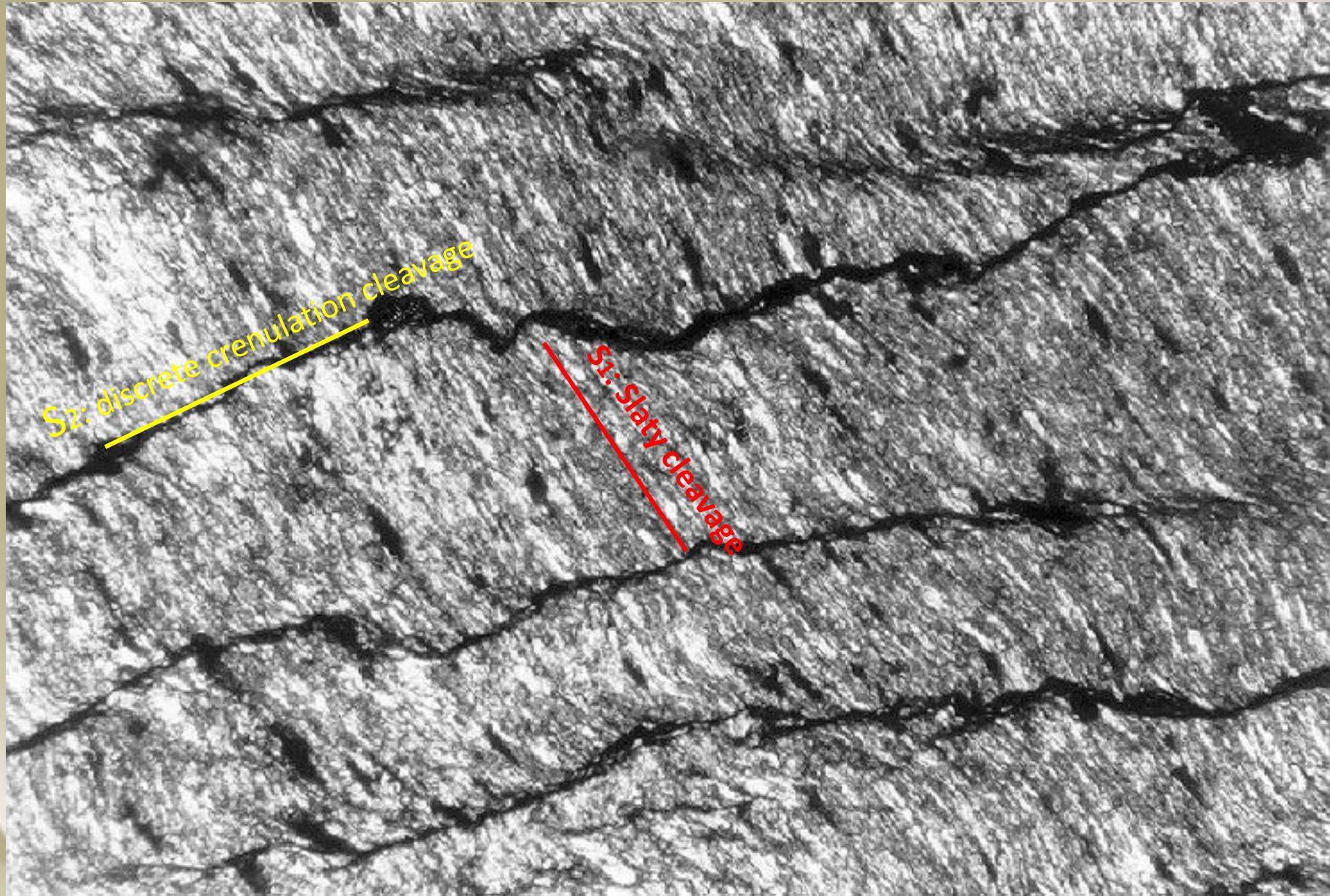


New foliation is along the axial of the fold with the old foliation as the folded surface



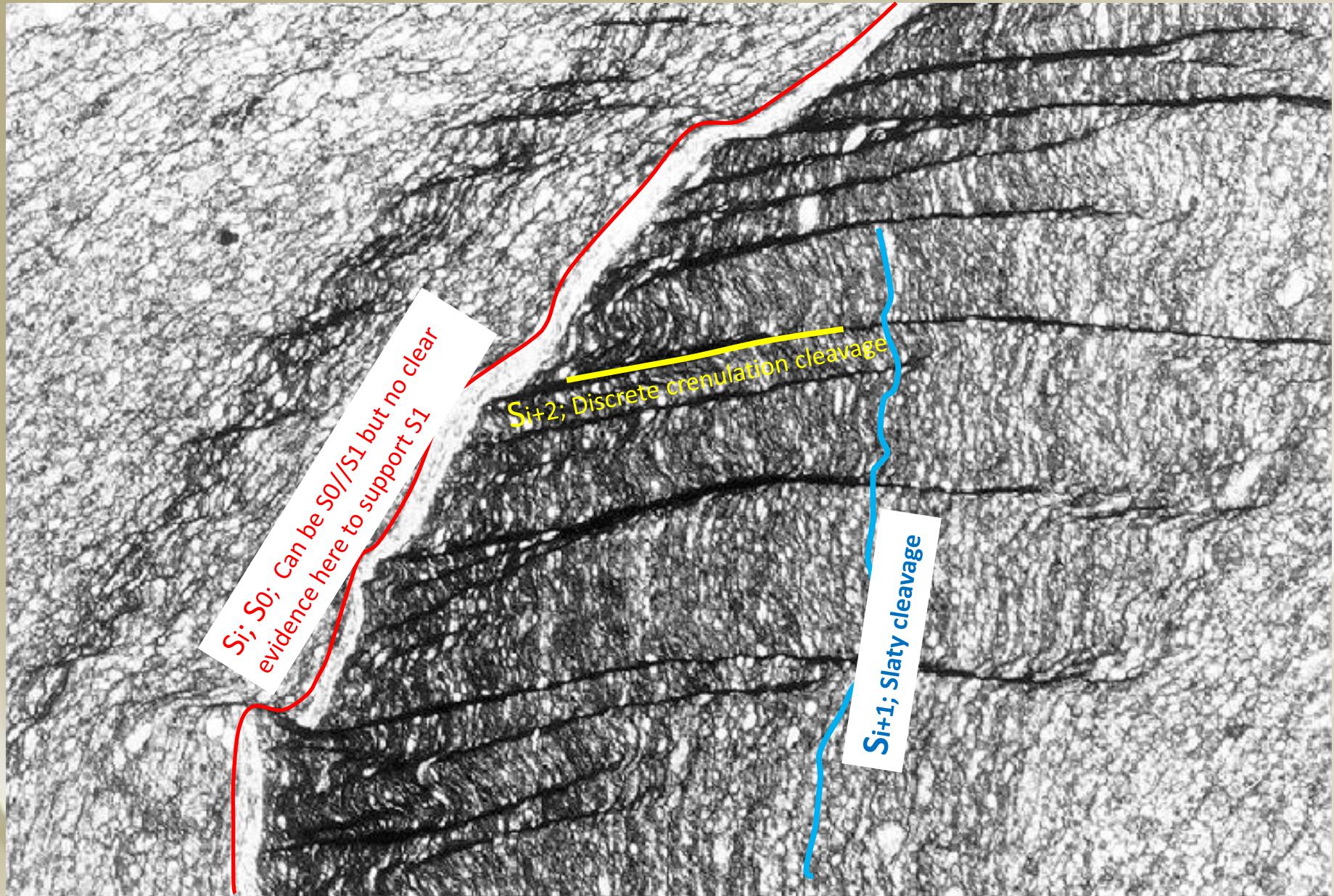
Where are the foliations? Lineation?





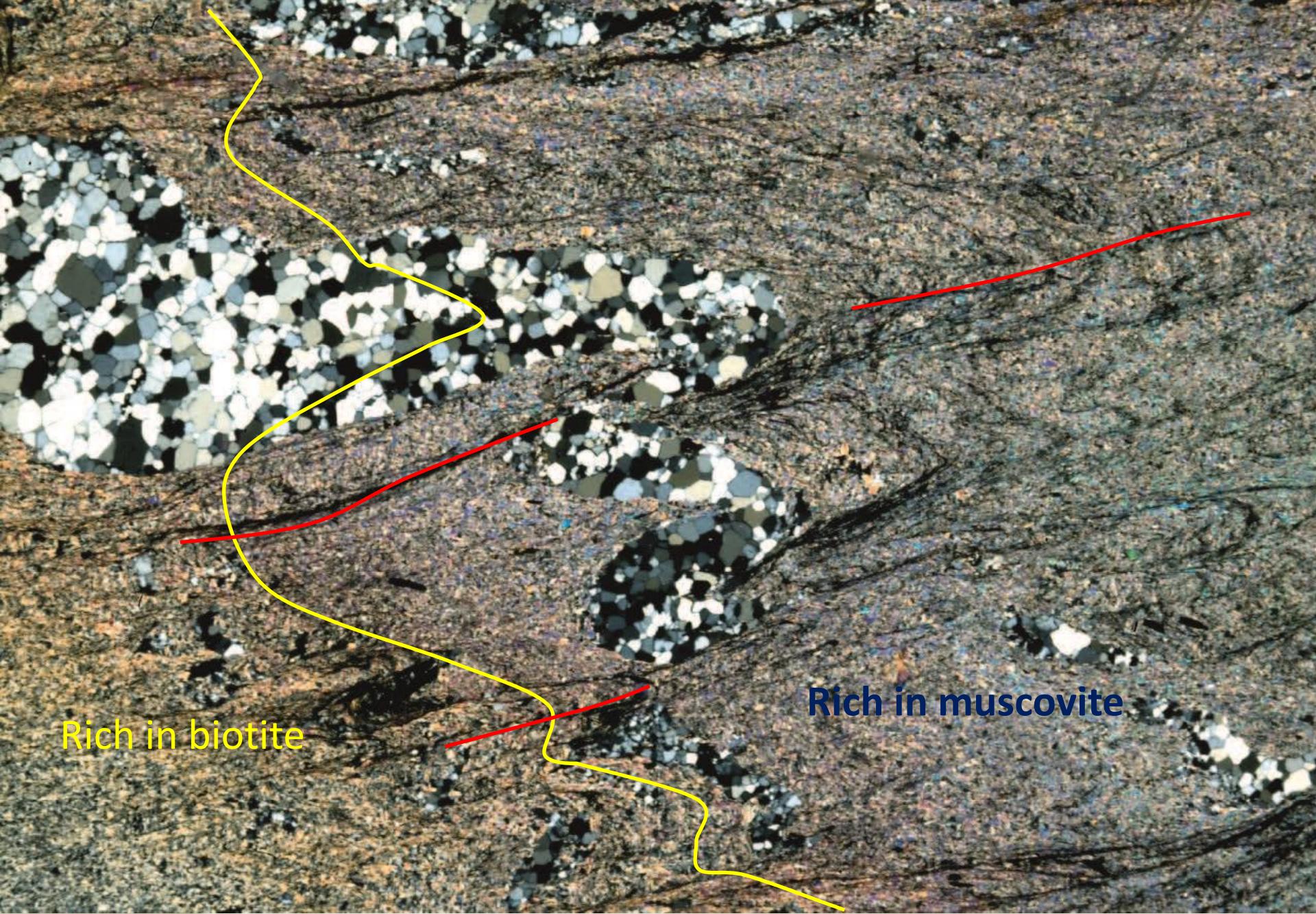
Passchier and Trouw (2006)

Width of view: 1.8mm

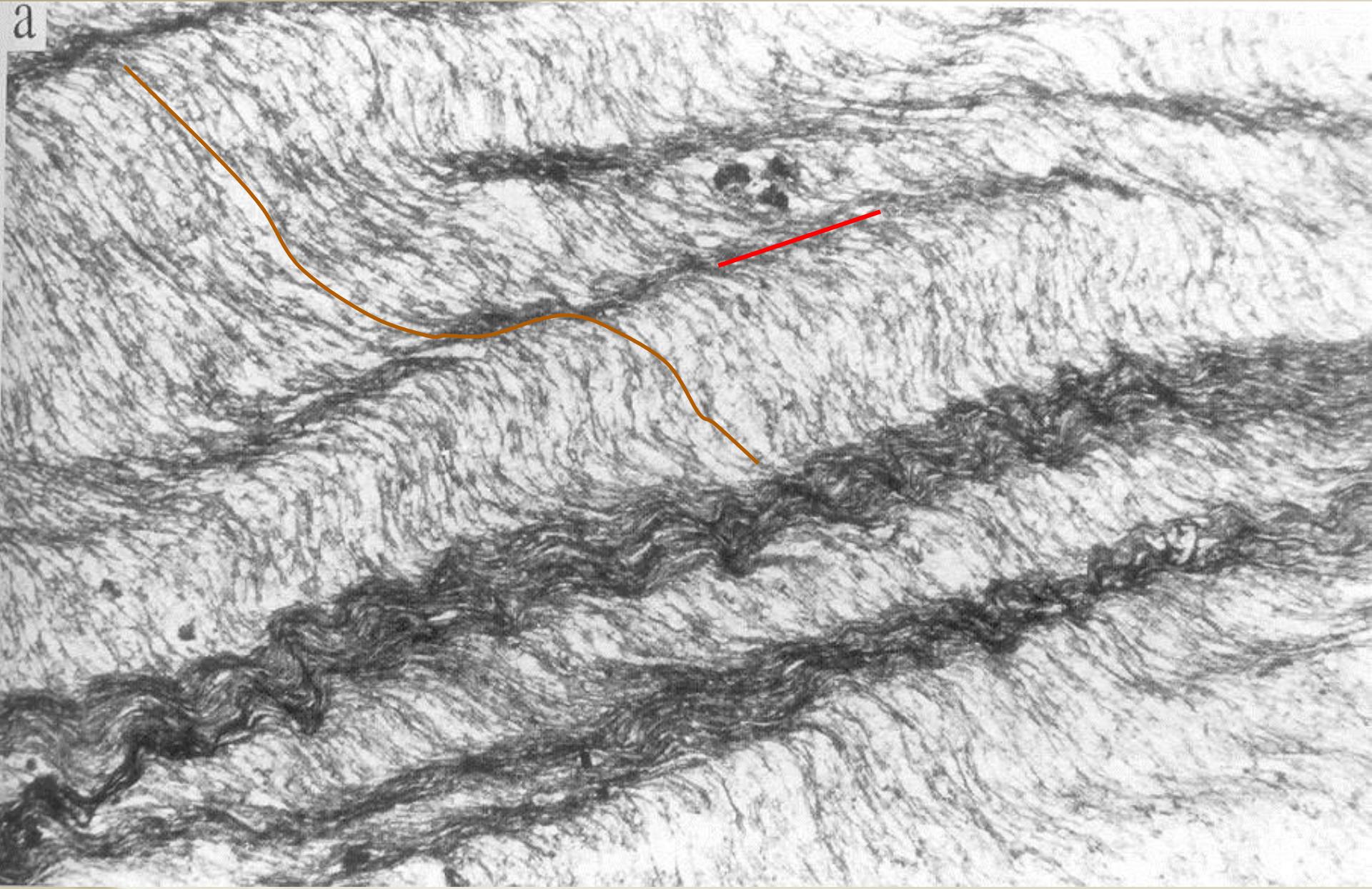


Passchier and Trouw (2006)

Width of view: 4 mm



a



Passchier and Trouw (2006)

Multi-generations of crenulation cleavage, FOV (Field of view) =4mm

# Sequence of events leading to selective refolding of a second foliation

